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Assessment of Scientific Graphical Literacy of 10th Grade Students in Al-Ain Educational Office, United Arab Emirates

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ASSESSMENT OF SCIENTIFIC GRAPHICAL LITERACY OF 10TH GRADE STUDENTS IN AL-AIN EDUCATIONAL OFFICE, UNITED ARAB EMIRATES

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This thesis is submitted in partial fulfillment of the requirements for the degree of Master of Education (Curriculum and Instruction)

Under the Supervision of Dr. Hassan Hamad Tairab

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Declaration of Original Work

I, Sarah Elkhaier Elhassan Hamad, the undersigned, a graduate student at the United Arab Emirates University (UAEU), and the author of this thesis entitled "*Assessment of Scientific Graphical Literacy Of 10th Grade Students In Al-Ain Educational Office, United Arab Emirates*", hereby, solemnly declare that this thesis is my own original research work that has been done and prepared by me under the supervision of Dr. Hassan Hamad Tairab in the College of Education at UAEU. This work has not previously been presented or published, or formed the basis for the award of any academic degree, diploma or a similar title at this or any other university. Any materials borrowed from other sources (whether published or unpublished) and relied upon or included in my thesis have been properly cited and acknowledged in accordance with appropriate academic conventions. I further declare that there is no potential conflict of interest with respect to the research, data collection, authorship, presentation and/or publication of this thesis.

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Abstract

The purpose of this study was to investigate the scientific graphical literacy level of the 10th grade science students, and explore the extent to which students at 10th grade have the essential skills to process and interpret visual scientific graphs in the private and public schools in Al Ain educational Zone. This study was exploratory survey design in which an attempt was made to explore student understanding of scientific graphs. A Graphical Literacy Test was developed for this study to evaluate the student ability to interpret, and construct graphical information. 125 grade10th science students participated in the present study. Sixty two of them were female and the rest (63) were male students. Out of the sample, 95 of the students were from public schools.

The result showed that students have better performance in graph interpretation than graph construction; students exhibited graph interpretation misconception related to graph "visual perception", "graph recognition", and "reading multiple graphs; misconception related encoding Information into a line graph, and mathematical knowledge of graph construction. There was a statistically significant association between 10th grade student graphical literacy and their level of graph interpretation, and graph construction. Female students significantly outperformed their males in graph literacy level, graph interpretation performance, while both female and male students showed poor performance in graph construction.

Based on the findings reported in the present study, the present study have educational implications for curriculum planners and developers, science teachers, and students in relation to how to adequately develop graphical literacy in students. Based on the findings reported in the present study, more research studies are needed to further explore students' difficulties with graphical skills and how graphical literacy is developed by students.

Keywords: Scientific graph, scientific graphical literacy, misconceptions, UAE.

Title and Abstract (in Arabic)

تقييم مهارات الرسومات البيانية العلمية لطلاب الصف العاشر بمنطقة العين التعليمية بدولة الإمارات العربية المتحدة

ملخص

الغرض من هذه الدراسة التعرف على مستوى الأداء العلمي لطلاب العلوم في الصف العاشر، واستكشاف قدراتهم في معالجة وتفسير الرسوم البيانية العلمية في المدارس الحكومية والخاصة في منطقة العين التعليمية. وتم استخدام اختبار لقياس مهارات الطلاب في فهم قراءة ورسم الرسومات البيانية. شارك مئة وخمسة وعشرون طالبا وطالبة من الصف العاشر، اثنان وستون منهم إناثا وثلاثة وستون من الذكور. وكان عدد المشاركين من المدارس الحكومية خمسة وتسعون طالباً.

لقد أظهرت نتائج الدراسة أن أداء الطلاب في قراءة وفهم الرسومات البيانية أفضل من فهم البيانات وتحويلها إلى رسومات بيانية. كما أظهرت نتائج الدراسة من ناحية أخرى أن الطلاب لديهم صعوبات في قراءة الرسومات البيانية متعلقة بالإدراك البصري، وفهم الرسم البياني، وقراءة رسوم بيانية متعددة. كذلك يوجد سوء فهم لدى الطلاب متعلق بترميز المعلومات في خط الرسم البياني، والمعرفة الرياضية لبناء الرسم البياني. كما أوضحت الدراسة التي طبقت على طلاب الصف العاشر وجود دلالات إحصائية مؤثره تربط بين مستوى المهارات البيانية ومهارات قراءة الرسوم البيانية من جهة ومن جهة أخرى بين مستوى المهارات البيانية ومستوى رسم الرسوم البيانية.

كما اوضحت نتائج الدراسة تفوق الإناث على الطلاب في المهارات البيانية ومهارات قراءة الرسوم البيانية، بينما كان أداء الإناث و الذكور ضعيفا في رسم الرسوم البيانية.

من خلال نتائج الدراسة تم تحديد تطبيقات تعليمية ليستفيد منها المختصين في تخطيط وتطوير المناهج حتى يتسنى لهم تطوير مهارات الرسومات البيانية لدى الطلاب. وبناءً على نتائج الدراسة الحالية تم تقديم اقتراحات لبحوث مستقبلية والتي من شأنها التقصي والبحث في مهارات الرسومات البيانية وأسباب العجز في أداء الطلاب.

مفاهيم البحث الرئيسية: الرسم البياني العلمي، مهارات الرسوم البيانية العلمية، مفاهيم علمية خاطئة، دولة الإمارات العربية المتحدة.

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Finally, I must express my very profound gratitude to my parents and to my husband for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. Special acknowledgment to my beloved sister Hana for her unwavering support, and enormous help. This accomplishment would not have been possible without them. Thank you.

Dedication

This thesis is dedicated to my family, my parents, my supportive husband, and kids, my brother, and sisters

For their endless love, support, and encouragement

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Chapter 1: Introduction

1.1 Background

In recent years the goals of science education have shifted toward cultivation of scientifically literate students with competencies and inquiry skills that can match the demands of the 21st century. Most recently the next science generation standards have affirmed this shift ,(AAAS,2015) This focus on the development of scientific inquiry skills is intended to help students acquire higher-order level of thinking skills and competencies needed for the evolving and changing societies. Furthermore, it was assumed that getting the right balance of scientific literacy will allow students to use their knowledge and skills in different situations and accordingly, make the effective and responsible decisions. To cope with the demands of the ever changing world students must have the competence skills of data management and data handling. One aspect of data management and data handling is the ability to read and interpret graphical information.

Scientific graphs are effective visual tools in representing scientific data. They are tools that present information in concise and clear ways that allow meaningful understanding of information. The visual representation of information simplifies the understanding of complex quantitative information, and successfully delivers understanding better than any other format (Burke, 2007). Scientific graph interpretation and construction are two skills that play a great role in understanding science and other social sciences (Roth and Bowen, 2001, p. 159). In the digital age

the student ability to read and construct graphs is not only useful to achieve curricular goals of science education but also to understand issues related to everyday life such as medical reports, financial data, and sports related data in the media.

According to Dreyfus and Eisenberg (1990) reading and constructing scientific graphs is a complex task. In order for students to interpret graphs they must have the ability to read and communicate meanings of the information presented in these graphs. Furthermore, they must have the interpretation skills such as organizing data, finding the relationship between these data, and identify patterns in the presented variables. Moreover, graph interpretation is also affected by the visual characteristics of the graphs, and to the degree to which students are familiar with different forms of graph visual representation. Previous research findings such as those of Freedman and Shah (2002), and Shah (2002) suggested that not only the visual characteristics affect student ability to construct, or interpret graphs, but also the nature and the quality of student's prior knowledge and proficiency in the numerous skills of graph literacy.

Therefore, it can be said that aspects such as visual characteristics, graphical literacy learners' prior knowledge, and whether students have the skills to process graphs are among the factors that impede graphical understanding. Graph visual characteristics, such as format, colors, and data organization, etc. were also found to greatly influence student ability to interpret and obtain the meanings from the

graph. Understanding of the graphical information is also affected by individual prior knowledge, such as the prior knowledge of the content presented in the graph, or the knowledge of the reasoning skills needed to interpret the graphical information.

United Arab Emirates has undergone numerous educational reforms in order to prepare students to cope with the demands of the 21st century. With the emphasis on the knowledge-based economy and data management, science education at the United Arab Emirates emphasizes the need to develop graphical literacy skills and recognizes the need to prepare students with the right balance of knowledge and skills (ADEC, 2010). Previous research findings related to graphical literacy suggested that UAE students do not have the necessary skills to interpret and construct scientific graphs (Tairab and Al-Naqbi, 2004). They found in their study that students struggled with questions that require drawing conclusions and interpretations from given scientific graphs. Furthermore, the researchers found that ability to construct scientific graphs was way behind the ability to read them. The authors recommended further studies to investigate the possible reasons of lack of graphical literacy among UAE students. Given the importance of graph interpretation and construction as critically needed skills, and previous findings related to UAE context have given emphasis and motivation to this study.

1.2 Statement of the problem

In order to make sure that the stated goal of education in UAE of having scientifically literate citizens are achieved, it is important to explore how students approach scientific graph interpretation and construction. To cope with the demands of the ever changing world, students not only need to acquire scientific knowledge but they must be able to apply this knowledge in different conditions as critical thinkers. In today's science education students are supposed to have analysis skills such as graph understanding and communicating the relationships included in graphs. In addition, if students acquire higher level of thinking skills and master the processes skills they will become productive citizen in the society, and they will have better life. The problem of this study is to investigate student' level of graphical literacy, and the difficulties associated with understanding of graphs. Given the emphasis placed by Abu Dhabi Educational Council (ADEC) in developing and design curriculum that meet the needs of the Abu Dhabi children. In addition, the focus of ADEC's vision for teaching and learning is that students should be able to think critically and communicate effectively and succinctly using high levels of knowledge. This study is valuable, and will be worth investigating how much students in ADEC should know and be able to do with problems involving graph interpretation and construction. Therefore ADEC focuses on higher order thinking skills, analysis, synthesis and effective communication – essential skills for success in the 21st century.

1.3 Purpose of the study

The purpose of this study is to investigate the graphical literacy level of the 10th grade students, and explore the extent to which students at 10th grade have the essential skills to process and interpret visual scientific graphs in the private and public schools in Al Ain office. Specifically the study focuses on the following purposes:

1. to identify graphical literacy level of 10th grade science students;
2. identify possible misconceptions possessed by 10th grade science students regarding the graphical literacy;
3. to compare 10th grade science student graphical literacy at the level of interpretation and construction; and
4. to compare 10th grade science students' graphical literacy according to student gender.

1.4 Research Questions

Research questions are essential parts that frame the research path (Gay, Mills, and Airasian, 2011). Research questions represent the core of any research, and the issue that researchers are genuinely curious about. The research questions of this study tried to explore the level of scientific graphical literacy of 10th grade students in Al Ain in UAE. Specifically the study attempts to find answers to the following questions:

1. What are the graphical skills 10^{th} grade science students have?
2. What are the possible misconceptions possessed by 10^{th} grade science students regarding the graphical literacy?
3. Are there any statistically significance relation between 10^{th} grade science students' graphical literacy and their level of interpretation and construction?
4. Is there any statistically significance differences in graphical literacy related to student gender.

1.5 Significance of the Study

Graphs are powerful tools and have great impact on people daily life activities, such as understanding graphical representation of information presented in the media, weather news, advertisements, health and environmental reports, political advertisement, and stock market. The significance of graphing literacy in science is showed by the emphasis placed on graphing proficiency in many science curriculum projects according to Berg and Smith, (1994); Padilla (1986). Graphs are used to summarize large amount of quantitative information in simplified way (Brasell, 1990; Garvin, 1986). Furthermore, to understand the science concept and to have the skills of scientist, students need to be able to deal with graphs comfortably (Rogers, 1995). It is important therefore to identify the level of graphical literacy among students and examine factors that may impede the development of such literacy. Recent curricular reforms in ADEC advocated the development of student skills in area related to data management and handling. Specifically they are focusing on

higher order thinking skills, analysis, synthesis and effective communication – essential skills for success in the 21st century.

From these perspectives, the significance of this study can be related directly to curriculum planners and developers, science teachers, and students. The study outcomes will contribute to curriculum planner via providing them with clear analysis of the student level in scientific graph interpretation, and construction, and by identifying the type of difficulties encountered by the students, therefore; it is expected that the study findings will guide the curriculum planner to show more emphasis integrating the need of the basic science processes skills such as observing, inferring ,analyzing and predicting in the curriculum building . Moreover teachers will adapt their teaching styles, and method to suit the new climate of scientific inquiry. Furthermore, throughout their teaching they will determine student's needs, which can be addressed during the next stage of study, and will significantly help and support the curriculum development to enhance students graph developing skills.

It is expected that the results of this study may help curriculum planners and developers, science teachers, and students to make the development plan that focus on graphic literacy instruction through integrating these skills in the curriculum, or by focusing on the teachers professional development activities that might impact students learning.

1.6 Limitation

The area covered in this study is relatively small (Al-Ain city) consisting of limited number of schools, which will certainly affect the results obtained. As a result the sample performance in graphical tasks used in this study may not reflect the true abilities of the students of the whole ADEC schools. The sample involved in this study has had relatively little formal instruction about graphical literacy science. This can be seen from the current science curricular taught at this grade level where by the practice of scientific graphs is limited informally to fulfilling and achieving related learning activities, rather than explicit instruction in scientific graph. As a result, it would be difficult to interpret what the results of this study may imply for students with more experience with graphical skills.

Another limitation that can affect the outcomes of the present study is the response of students regarding the participation in answering the test. The conclusion to be drawn from this study is based on participants' responses and as such the authenticity of responses collected to a large extent will influence the findings. Finally, this study has focused only on limited number of public, and private schools in Al-Ain educational zone due to time frame and other logistical circumstances, and therefore the ultimate findings must be interpreted within this context of these schools only.

1.7 Delimitation

This study is limited to selected sample of 10th grade science students in Al-Ain who followed ADEC curriculum. The data collected during the academic year 2013-2014 using a specifically developed graphical literacy instruments.

Operational definition of terms

Scientific graphs: Are formats used to display scientific data, or to illustrate information that is difficult to describe with text, in textbooks and other popular print or electronic media (Shah, Mayer and Hegarty 1999; Renshaw, Finlay, Tyfa and Ward 2004; Shah and Hoeffner 2002; Van Tonder and De Lange 2002).

Graphical literacy : Refers to the ability to construct, produce, present, read and interpret charts, maps, graphs, and other visual presentations and graphical inscriptions (Readence, Bean and Baldwin, 2004). Graphical literacy according to Tonder (2010), is used to mean the ability to represent construct, produce, present, read and interpret charts, maps, graphs, and other visual presentations and graphical forms. Furthermore, graphical literacy has many definitions and can be explained as the ability to understand an image or a graph and basing this understating on the knowledge of different visual element and the ability to think.

Assessment of graphical literacy: Is defined in this study as evaluating students ability to interpret and construct scientific graphs using a specific test.

Graph interpretation ability: The term was defined in the literature as the ability to obtain meaning from graphs, created by others or by themselves, and as a fundamental skill that essential for all students in their everyday life (Glazer, 2011).

Graph construction ability: The term graph construction ability was defined by Brasell (1990:72) as the ability to present data into graphical format using specific skills, including the ability to select the appropriate graph form, identify the relation between, choosing the appropriate axis, drawing and scaling axes, plotting points on graph from provided data, titling the graph and annotating a graph. In this study the term graph construction ability is used to denote the ability to graph any type of data, with the appropriate from of graph.

Test of graphing skills (TGS): The Test of Graphing skills (TGS) was specifically and systematically developed to evaluate the student ability to interpret, and construct graphical information.

Chapter 2: Literature Review

2.1 Introduction

This chapter presents and reviews major findings of related previous studies that investigated the area of constructing and interpreting graphs. In particular the reviewed literature illustrated the knowledge about graphs definition, importance, comprehension of graph, graphical literacy, graphing skills, the difficulties associated with graph interpretation, and the studies that investigated the science student graphical skills in the context of United Arab Emirates (UAE).

2.2 Conceptual Framework

This study is grounded on the constructivism learning theory and the Ausubel's meaningful learning theory, which argued that learners are able to construct their knowledge and understanding, through relating the new information with their existing or prior knowledge. Within this framework, the development of graphical literacy is viewed as personal engagement of the learner with graphical information. Therefore, the degree of involvement is largely influenced by the amount and quality of the learner interaction with the graphical information. Learners are expected to actively engage in trying to make sense of graphical information Furthermore, this study relied also on Ausubel's meaningful theory (1968) who suggested that learning vary from highly rote learning to highly meaningful learning. According to Ausubel's theory learner are able to construct their meaningful learning or their understanding by assimilating the new information with the prior knowledge

(Ausubel, 1968). In graph interpretation or construction students need to use their prior knowledge to construct their meanings and understanding for graphical data. In fact, students are actively engaged in reading the presented data and relating them to their previous experience to conclude their understanding. Moreover, this study is also based on how visual representations are more effective in delivering understanding, and speeding up recognition and retention of the information. Ormrod (1998) has illustrated three forms of meaningful learning which are elaboration, organization and visual imagery. Visual imagery is another effective strategy that is more effective than language, i.e. often easier to cognitively ingest and manipulate information presented in a visual display (Dansereau, and Simpson, 2009). Therefore, graphs are visual representation of large or detailed amount of quantitative data in abbreviated format that easier to understand. This study investigates the student's proficiency and deficiency in interpreting and constructing graphs. Furthermore, it highlights the major factors that influence their abilities in interpreting graphs.

2.3 What is a scientific graph?

According to Readence, Bean and Baldwin (2004) graphical literacy is defined as the ability to construct, present, interpret, and read charts, maps, graphs, and other visual demonstration and graphical representation. Graphical literacy is also used to denote the ability to communicate, analyze, and generate meanings from the quantitative information. Moreover, graphs as a scientific concept have been defined in researches studies as (Renshaw, Finlay, Tyfa and Ward, 2004; Shah,

Mayer and Hegarty 1999; Shah and Hoeffner 2002; Van Tonder and De Lange 2000). Tonder (2010) defined graphs as visual representation of scientific data, or to clarify difficult information with text, in textbooks and other popular or print or electronic media. In addition, graph is also termed chart, which is defined as "drawing depicting the relation between certain sets of numbers or quantities by a series of dots, lines, etc., plotted with reference to a set of axes" (Collins English Dictionary, 1991: 674). Wenner (2009) defined scientific graphs as visual representation of numerical systems and equations. Other researchers defined graphs as data summarization techniques, which are quickly convey information enabling fast and accurate data extraction (Fischer ,2000; Hink, Eustace, and Wogalter,1998).

Given the various perspectives and definition of graphs in previous research studies, it is clear that all the researchers agree on the notion that scientific graphs are tools that provide clear and concise meanings from complex set of data, and hence they can be regarded as tool that help learner simplify massive data into meaningful information.

2.4 Why scientific graphs are important?

Kali (2005) described scientific graphs as a powerful tool that give people summarized descriptions about quantitative data and even categorized data. Graphs are important in the daily life of all individuals, to interpret different finding about the sports game, medical reports, cosmetics statistics, .etc. Graph reading skills are important for adult, either in their professional jobs as educators in teaching science

or in their general daily events. Similarly, graphs are important for students to interpret scientific data, and even to understand it (Jackson ,1993). Furthermore, graph's importance can be summarized as the fact they are robust in summarizing data from large amount of data into abbreviated and obvious visual representation (Garvin,1986; Brasell, 1990). According to Rezba (1998) graphs reflect information in simplified form that can be interpreted very easily.

Brasell (1990) and Stannard and Williamson (1991) suggested that, graph can provide a wide, and clear description of the relationship between the measured data. Graphs are important factor that help student in using their knowledge and apply in graphical form that lead to their understanding of abstract form that are difficult to grasp directly (Gattis and Holyoak, 1996). Likewise, Wenner (2009) claimed that graphs help visual learners to visualize the relationship of one bit of data to another, so they will be able to translate them into meaningful knowledge.

2.5 Scientific graph comprehension

Pinker (1990) described graph comprehension as the process of the understanding and extracting information from graph. There are different mechanisms or techniques that help readers of graphs to read and interpret the information from them. The most important factor that help graph interpreter is the familiarity with visual characteristics of the graphs. Being able to understand the visual characteristics of graphs will that help readers to figure out the meanings from the graphs.

2.6 Visual characteristics of scientific graph

Cara, Wendy and Arthur (2008) indicated that graph reading is highly influenced by the degree of variation and complexity of the presented data. Moreover, they suggested that graphs data should be clearly illustrated for readers to be interpreted easily. Therefore, they directed to an important point that the designer of the graph should consider making the graphs understandable to the users, and make it easy to understand the represented data. The successful graph comprehension is based on the type of the graph and, the visual characteristics of graph (Cara, Wendy and Arthur, 2008). Graphs have many characteristic such as the scales, axis orientation, the gridlines, the legend, and the dimensions whether three or two dimensions, the colors, and the backgrounds. Those characteristics can affect the quality of the graph and the information displayed. For instance, using legends and labeling in a graph will really help the readers in refreshing their memories and retrieving the intended data and information that are concluded by the graph. Another characteristic is the background; when a background picture is added to the graph it might hinder the vision and impair the performance as it could make it difficult for the reader or the user of the graph to read the graph and it will require more search as the background will reduce the contrast between the targeted information and the background information. The use of dimensions will enhance the graph and therefore will draw readers' attention to the graph while a 3-D graph can result in alteration of the data which will eventually result in an incorrect comprehension of the presented data (Cara, Wendy and Arthur ,2008).

2.7 Studies related to scientific graphs comprehension

Glazer (2011) showed from previously reviewed literature that graph comprehension involves three main processes: Firstly graph readers need to recognize visual array and the important visual features (such as a curved line). In addition, interpretation of visual information is influenced by the graph visual characteristics and the way data is presented (Bertin, 1983; Carpenter and Shah, 1998; Clevel,1985;Kosslyn, 1989; Pinker, 1990). Secondly, according to Bertin (1983), Kosslyn (1989), and Pinker (1990) graph interpreters must relate the visual features to conceptual relations that are represented by them. Moreover, the ability to derive conceptual relation from the visual representation appears to be influenced by several factors, such as the outcome of graph comprehension and the ability to map between the visual representations, which are also affected by the reader graphing skills. The third process is the viewer ability to associate between quantified concept and the determined function (Bertin, 1983).

Cara , Wendy and Arthur (2008) stated in their study that the scientific graph comprehension requires the consideration of many elements and factors in the graph designing process such as; task requirement, data features, graph characteristic and users' characteristic. These factors are interrelated as they cannot be untangled, and they reflect the reading process which makes the graph reading sophisticated as these factors are interacted with each other (Cara, Wendy, and Arthur, 2008). Furthermore, they claimed that the graph constructor has to consider the targeted readers and users of the graph by considering different human factors when designing the graph. One

factor is the physical and the perceptual characteristic of the user that requires designer to do many reading tests by displaying the graph for some of the representative users to ensure that the graph designing is going in the right track (Cara, Wendy, and Arthur, 2008). User task requirement can be specified by particular point in the graph, comparing the values that are included in the graph, trends reading and trends comparison (Cara, Wendy, and Arthur , 2008). Additionally, they illustrated that some of the tasks might ask for deriving particular values from the quantities shown in the graph, another task might ask for extracting and understanding the relationship between the chart elements or variables. Moreover, they indicated that the ideal graph helps the graph users in finding their task requirements by reducing the dependence on the users' information via using the direct labeling rather than requiring them to compare the graph legend with the graph content. Finally, they presented that complexity of the presented data can affect the comprehension of the graph like the number of variables, lines displayed, the trend of the line drawn i.e. up and down movement and the number of the data points.

2.8 Scientific graphical literacy

Tonder (2010) conducted a quantitative study using cross-sectional method to study third-year biology classes graphical literacy, which represent the ability to construct, produce, present, read and interpret charts, maps, graphs, and other visual presentations and graphical forms. The writer talked about the dual-coding theory which says presenting information in verbal and visualized form has greater impact

in retaining and memorizing the information presented, therefore, combining a text with a graph makes it easier to retrieve the information and enhance learning skills. He also affirmed that visualization tools are really important in the problem solving of daily activities. Tonder (2010) defined graphs as visualization tools such as physical and molecular models, photographs, micrographs, pictures, diagrams, metabolic maps, graphs and animated visuals, collectively known as external representations. These tools particularly graphs illustrate information in a visual form, and it is valuable in making the students using their cognitive abilities and stimulating them to build mental images that helps them in understanding and retaining information. Constructing such visual forms requires skills and experience in a particular field of knowledge and these skills are called visual literacy.

Visual literacy has many definitions and can be explained as the ability to understand an image or a graph and basing this understating on the knowledge of different visual element and the ability to think. Generally, visual literacy is the ability to communicate with pictures but the graphical literacy is ability to communicate with graph (Andre, 2010). Nowadays graphs and visual presentations are required more than the need for reading and writing. Shah and Heffner (2002) stated that the graph reader are impacted by their interpretation of the data and this can be affected by the reader beliefs and expectations ,and the students has to know that graphs are not only a tool for information delivery.

Glazer (2011) indicated that data presented in graph improved in multiple contexts and mainly into context reading and enquiry. In inquiry individuals have to

understand data and make their own investigations of the data presented and interpret it in order to report their own findings. In the everyday reading context that is needed for the scientific literacy the readers are not actually engaged in an investigation of the data but they only have to understand the data and the logic behind it. Generally, scientific graph used for interpretation can be found everywhere in the textbooks or in the newspaper. As mentioned before graph interpretation is the ability to understand graphs and it is a basic fundamental skill needed in the everyday life.

2.9 Student misconceptions associates with graph interpretation

Although scientific graphs are viewed as important tools that aid comprehension of scientific content, many research studies have shown that students often experience difficulties in understanding graphical information. For example, Glazer (2011) stated there are challenges concerning graph interpretation as reading graph is not that easy task, thus the experts or the designer of the graph has to design the graph to be meaningful for the students and the users of the graph by considering the users knowledge and expertise. Student difficulties are categorized into different areas such as the slope and the height confusion, interval and point confusion, envisioning graphs as pictures or maps, and visualizing a graph as constructed of separated points. Usually slope and height confusion happen when the student or the graph reader replace the height with slope values and this might be considered as an obstacle for identifying the pattern changes when graphing the variables against time. Confusion of interval point happens when the graph reader focuses on single

points rather than the interval just like what happens when a comparison of two populations' growth is done. Moreover, considering graph as picture or map rather than representation of the relationships between different variables. Additionally, considering that a graph is constructed from discrete points for instance, when the graph reader reads the graph as separated points by counting the actual number of points in graph which make it difficult for them to understand the meaning of the graph. Another mistake is to connect between the points rather than applying the convenient line trend i.e. when drawing a straight line in the case of linear data. Furthermore, some of the difficulties with graph interpretation consequence from the volume and the amount of the data presented in the graph or the format that is used to present the graph (Glazer, 2011).

Padilla (1986) revealed that there is gradual development in graph construction and interpretation from the 7^{th} to 12^{th} grade with exceptions related to 11^{th} grade. Berg and Phillips (1994) found that students in higher grades have more logical thinking to construct and read graphs. likewise , Wang, Wei, Ding, Chen a , Wang a and Hu (2012) found that student's graphing skills enhance as they move from one grade to a higher grade. Wang, Wei, Ding, Chen, Wang and Hu (2012) showed that there is variation among elements related to graph information such as explicit, tacit, and conclusive information. In addition, they illustrated that students in higher grades are more capable to identify the explicit information. They attribute this to the students learning development due to their continuous exposure to more

graphs and different types of graphs which provide them with more experience and more understanding of the nature of graphing process.

Increasing of student's logical thinking will influence students' knowledge and problem-solving skills. Moreover, this will affect both student's ability in reading the graph and using the information in the graph. As a result of identifying the characteristics of student's graphing skills in each age clear dynamics on how to develop effective ways to emphasize on their abilities can be concluded.

Leinhardt, Zaslavsky, and Stein (1990) in their extensive review in mathematics education on functions, graphs and graphing used the term misconceptions and classified students' difficulties in this area into four kinds of categories:(1) confusing the slope and the height, (2) confusing an interval and a point, (3) considering a graph as a picture or a map and (4) conceiving a graph as constructed of discrete points. Although this study dealt with mathematical discipline it points to the importance of graphical literacy where by it shows the importance of having graphical literacy by students across discipline.

Friel, Curcio, and Bright (2001) identified three main components of graph comprehension; these components show a progression of attention from local to global features of a graph: (a) To read information directly from a graph, one must understand the conventions of graph design; (b) to manipulate the information read from a graph, one makes comparisons and performs computations; and (c) to generalize, predict, or identify trends, one must relate the information in the graph to the context of the situation. Shah and Heffner (2002) claimed that the x–y trends can

lead to incomplete interpretations of data when the data are complex for example multiple lines on a display representing a third variable.

Tairab and Al Naqbi (2004) claimed that difficulties with interpretation were relied to students' lack of the needed strategies to read graphs correctly such as understanding of the problem context, prior knowledge of the different forms and types of graphs.

2.10 Student misconceptions associates with graph construction

Previous research studies have also shown that science students show difficulties related to scientific graph construction. For example , Padilla (1986) in his examination of the line graphing ability of middle and high school students found that of the 625 students tested only 46% could correctly assign the variables. Other studies suggested that school students in the USA were unable to determine which variables from a data set are relevant to the task or how to assign the variables to the appropriate axes , and they showed a tendency to place time on the x-axis when plotting graphs, regardless of the data set provided" (Brasell, 1990: 80).

Tairab and Al-Naqbi (2004) in their study of 94 10^{th} grade biology students from two different contexts, one in Brunei and the other in the United Arab Emirates, found that some students could not see the relationship between the dependent and independent variables and how they should be plotted on the axes, and hence they were unable to construct graphs.

Kali (2005) in his reviewed literature described a number of studies that identified problems in constructing graphs, by both secondary and tertiary level

students (Berg and Smith, 1994; Brasell and Rowe, 1993; Mevarech and Kramarsky, 1997; McDermott, 1987; Padilla,1986). The difficulties were related to drawing, labeling and scaling axes, constructing a line of best fit/interpolating, failure to graph the relevant variables, failure to understand whether to obtain information from the slope or height of the graph, The "graph-as-picture" misconception picture of the event" phenomenon, Determining the x and y coordinates and plotting points.

Tonder (2010) mentioned that the difficulty in understanding a graph is not just a result of the characteristics of the graph or the graphic design elements but is also affected by how these characteristic and features interact with the reader knowledge and the visual characteristics of the graph, such as color and the format of the graph either two- or three-dimensional graphs.

In addition, Tonder (2010) found that students displayed notable deficits in graphical literacy capabilities. Problems with graph comprehension identified were finding ratios between data, identifying dependent and independent variables, interpreting slope and height changes on a curved graph, identifying and interpreting scale, using a second y-axis and multiple sources of information.

Shah and Hoeffner (2002) claimed that the potential readers of the graph also affect how the graph is constructed. For instance; if the graph viewer has high prior knowledge about the information would be presented in the graph then no matter how the graph is constructed then it would be easier to reader to understand as the prior knowledge of information assists in graph comprehension. Difficulties

surrounding graph reading and understanding graphs are many and one of the fundamental difficulties is to read the graph as a picture not as a quantitative representation of the information, another problem is the difficulty in identifying the graph slope, height, intervals and points and concentrating on the X-Y trends. One more point is the number of the information covered by the graph would increase the complexity of the graph. There are many challenges that represent obstacles when presenting data just like determining the medium of data display and whether to use table, graph or text. another challenge is how to design the material or the data to be displayed in a clear and understandable form. For the data to be effectively constructed the designer of the visual presentation has to identify the goals to present this information. Other challenges are showing data in an inadequate and inaccurate manner (e.g. using a bar graph instead of a line graph or not starting the y-axis at zero) and obscuring data (e.g. leaving in the grid or using a double axis graph with different scales). Furthermore, presenting data in a misleading way just like what happens by the advertising industry and the financial consultants. The general consensus is that the use of additional or non-informative features in a graphic display should be kept to a minimum as it is often unhelpful and distracting. The graphic theorist Tufte (1983) introduced the data-ink ratio concept which explains how the number of elements in a graph can be reduced without losing any information (Fischer, 2000; Bracey, 2004; Few, 2004). The goal of the graph designer, then, is to maximize the data-ink ratio without eliminating the necessary elements required for effective data communication (Few, 2004). Data ink can be

described as the core of a graphic display – non-erasable and necessary for communication (Few, 2004). Non-data ink is an additional, usually irrelevant, feature of a graphic display used to make it more attention-grabbing for the viewer (e.g. hard-to-read elaborate fonts, colorful or more shading and a pseudo third dimension) (Bracey, 2004).

2.11 Gender differences in scientific graphical skills

Research studies dealing with gender differences pointed to inconsistent gender differences when it comes to science achievement in general and graphical literacy in particular. However, there seems to be scarcity of previous research findings related to graphical literacy. Recent findings of TIMSS (TIMSS, 2011) found that there were significant differences in the average science scores of males and females of UAE student's science performance. However, these differences were not in graphical literacy. Nevertheless the study of Lowrie, and Diezmann (2009) reported that boys outperformed girls on complex levels of graphical decoding suggesting a superiority of male students over their counterpart when it comes to scientific graphical literacy. More research findings are needed in this area to concretely and reliably draw conclusion about the gender differences related to scientific graphical literacy.

2.12 Studies related to UAE/regional context

In the context of United Arab Emirates (UAE) there is only one research that examined 10th grade student's science graphical skills, and their abilities to read and

construct graphs. Tairab and Al Naqbi (2004) explored student's ability to interpret and construct graphical information, and the factors that may affect the process of graph interpretation and construction. Tairab and Al Naqbi (2004) found that secondary science students don't have the essential skills to interpret and construct graphical information. They suggested that more emphasis must be provided in the form of systematic instructional to highlight and integrate the needed graphical skills in the science curriculum.

Due to the inadequate studies done in the area of graphical literacy in the UAE context, more studies are needed to widely explore the students graphical abilities, investigate the areas of student's deficiency, find the reasons behind these deficiencies, and provide practical and significant solutions that will enhance the teaching and science learning practices.

2.13 Summary of reviewed research

This chapter provided expanded literature review that explored the area of student's graphical skills. The reviewed literature tackled different aspects related to scientific graphical literacy, such as the definition of scientific graph, the importance of graphs, graph comprehension , student misconceptions that are associated with graph interpretation, and focused on the studies related to UAE/regional context. Firstly, scientific graphs are defined as visual representation of scientific information that provide clarifications and trends related the represented information in simple way. Secondly, the importance of the scientific graphs which was described by

Lemke(2005) in the context of science education objectives which aims to prepare students to think in a scientific way. Students who have the essential skills of graphical literacy have most analytical skills that will help them to think critically and enable them to analyze, judge , infer, and become good decision makers. Kali (2005), showed that graphs are powerful tools that give people summarized descriptions about quantitative data and even categorized data. Moreover, graphs are important in the daily life for both gender male and female, to interpret different information such as sports game, medical reports and cosmetics statistics.

Thirdly, the studies about graph comprehension showed that the process of comprehending graph is affecting by different factors such as understanding the visual format of the different graphs. Visual characteristics of graphs can affect the quality of the graph and the information presented in the graph. For example, Graph's scales, axis orientation, the gridlines, the legend, and the dimensions whether three or two dimensions, the colors, and the backgrounds, these characteristics plays a significant role in helping graph reader to interpret the graph. In addition, graph comprehension involve three main processes, graph readers need to recognize visual array and the important visual features, graph interpreters must relate the visual features to conceptual relations that represented by them , and the viewer ability to associate between quantified concept and the determined function

Fourthly, the reviewed literature showed that students might have various misconceptions related to graph interpretation and construction. Student's

difficulties with graphical information were categorized into different areas such as the slope and the height confusion, interval and point confusion. According to the findings student age and grade affect their ability to read graphs, so when they are in higher grades they are more capable to think logically, and tend to read scientific graphs easily. Additional findings about student's misconception in graph construction are the challenges that represent obstacles when presenting data just like determining the medium of data display whether to use table, graph or text. Another challenge is how to design the materials data to be displayed in a clear and understandable form.

Finally the reviewed literature revealed that there is inadequate number of studies in relation to UAE context. Only one study was conducted in UAE/regional context that investigated 10^{th} grade student's science graphical skills, and their abilities to read and construct graphs (Tairab and Al Naqbi, 2004). This study addressed the student's ability to interpret graphical information, to represent graphical information, factors that impacted the process of graph reading and constructing among secondary school science.

Given the scope and the coverage of previous research studies dealing with scientific graphs, particularly in UAE context this study is designed to fill the gab mentioned in the literature and contribute to context-related finding particularly to UAE. It has become clear from the reviewed studies that students encounter learning problems related to graph interpreting and constructing scientific graphs. Hence, it is

anticipated that the findings of this study may highlight such learning problems, and suggest further steps needed to be taken by educators to improve shaded learning areas of scientific graphical interpretation and construction.

Chapter 3: Methodology

3.1 Overview of the chapter

This chapter presents information related to the research methodologies used to answer the research questions related to student graphical skills, deficiency in their graphing interpretation and construction, and the reasons behind these deficiencies. The chapter begins by providing detailed description about the context of the study, the processes used in the sampling and population selection, the development of the instrument used to collect the data about this research, the research design, procedure, and the data analysis techniques used to provide meanings to the collected data.

3.2 Context of the study

The context of this study was the 10^{th} grade science students of Abu Dhabi Education Council (ADEC) schools both public and private schools of the city of Al Ain and their science curriculum. Education in Abu Dhabi is organized into two main categories: public schools and private schools .ADEC public schools range from kindergartens to secondary school. The core learning years (from Grade 1–12) are divided into three cycles. There are currently around 185 private schools, and 257 public schools in Abu Dhabi Emirate. 10^{th} grade students are categorized as Cycle Three student which include students from Grades 10 through 12. The findings of the present study pertain to the context of Al Ain city, and ADEC curriculum and the general philosophy and vision of ADEC authority in relation to

preparing students to be able to function effectively in the society. Scientific graphs in ADEC science curriculum are generally regarded as a supplementary aiding tool in teaching science. Furthermore, graphs are being taught separately in math curriculum, without taking in to consideration the scientific process in manipulating the graphical information. Therefore, the science curriculum followed by ADEC has no explicit instruction about scientific graphs.

3.3 Participants

The sample of this research is a representative sample of 10^{th} grade students. They were conveniently selected for this study. Convenience sample is the one that fulfill the requirement of the research (Gay, Mills, and Airsian, 2011). The sample also meets the predefined criteria placed for this research such as language of instruction, nationality, and the curriculum provided. The sample of this study was selected according to their availability, and willingness of teachers to involve their students in the study. Altogether 125 grade10^{th} students participated in the present study. Sixty two of them were female and the rest (63) were male students. Out of the sample, 95 of the students were from public schools, while the remaining 30 students were from private schools. Furthermore, 115 students came from Arabic background and Arabic language is their first language, while 10 students come from English background and English is their first language. Among the sample, 91students were UAE nationals, and 34 were from other nationalities. Table 1 presents demographic information about the sample.

Table 1: Participant's Demographic Information

		Student Gender		Total
		Male	Female	
Student Nationality	UAE National	47	44	91
	Non UAE	16	18	34
School type	Public	49	46	95
	Private	14	16	30
Firs Language	Arabic	57	58	115
	English	6	4	10
Total		63	62	125

3.4 Instrument

A Graphical Literacy Test was developed for this study to evaluate the student ability to interpret, and construct graphical information. The Test of Graphing skills (TGS) was specifically and systematically developed in three main phases including item development phase, establishment of test psychometric properties (validity and reliability) phase, and preparing the test in its final form phase.

3.5 Item Development Phase I

The aim in item development was to map the content of the test and to identify areas related to the scientific graphs. The result of this phase was the identification of the following content areas:

1. Interpretation of given graphical data

2. Interpretation of key elements of graphical data related to physical knowledge
3. Extracting qualitative information from quantitative data
4. Interpretation of simple trends in graphs
5. Construction of graphs from tabular data of different graphical representation

Based on the above mapping, a content specification was drawn to outline the essential domains related to interpretation and construction of graphs. Essential domains such as reading key features from graphs, reading simple trends in graphs, mathematical computation skills, comparing information from two graphs, reading global trends in scientific graphs, and extracting qualitative information from quantitative information.

The content of the questions were selected from the 10^{th} grade curriculum, and from previous questions used in international assessments such as the International General Certificate of Secondary Education (IGCSE). The questions covered different graphical literacy skills of reading and interpretation of graphs. At the item development phase, 17 multiple choice questions with 4 answer options were developed. The questions covered different scientific areas taught in 10^{th} grade such as force, velocity, and ecology. The examination questions were developed to focus mainly in graph construction and interpretation. The questions covered different types of graphs such as line, bar, and pie graph. Table 2 provides description of specification of the content from which the questions were drawn, how many

questions under each category, the skill covered by each question, and they type of graph used. All graphs depicted in the questions were drawn using Microsoft Excel and imported into the test set up in Microsoft Word.

Finally two versions of the test questions were developed- the first one was in English and was used in the private schools and the second version was in Arabic which is an exact translation of the English version, and was used in the public schools.

Table 2: Table of Specifications of Test Content

Category	Question	Skills	Graph type
Interpretation	Q2, Q5, Q8, Q12	Reading key features from graphs	Line, Pie,
	Q3, Q16, Q17	Reading a simple trend in graphs	Line, Bar
	Q9, Q11, Q13	Reading key features from graphs, physics knowledge.	Line graph Free-body diagram
	Q 10	Basic reading of tables, graphs constructing, and mathematical operations.	Line graph
	Q14, Q15	Extracting qualitative information from quantitative information, and Comparing information from two graphs	Line graph
Construction	Q1, Q4, Q6, Q7	Constructing of graphs from tabular data	Line, Pie, Bar

Following the construction of the test items, the instruction on how to take the test as well as the collection of biographical information from the sample were decided. The demographic details requested from the students are nationality, school type, and instruction language. The second part of the test consists of the questions that are used to evaluate student performance in both graph interpretation and construction literacy.

3.5.1 Establishment of test validity and reliability phase

Test validity and reliability are important constructs of any instrument to be used in educational research. According to Gay, Mills, and Airsian (2011) for an instrument to be valid it must measure what is supposed to measure. They also described the term face and construct validity as a way to measure the instrument content and alignment of construct validity. Therefore, face validity is being used for instrument screening procedure of the test question. They also suggested that an instrument to be used to gather information it's not enough to be a valid test only, but it must be a reliable instrument. Reliability on the other hand is something to do with the consistency of the results collected by the instrument. Gay, Mills, and Airsian (2011) defined reliability as the degree to which a test consistently measure whatever what is measuring.

3.5.2 Establishing the validity of the TGS

In order to evaluate the face and construct validity of the developed TGS test, it was distributed to 5 science educators to review and evaluate the capacity of this

instrument in measuring the student's abilities in graph interpretation and construction. Additionally, they reviewed other aspects that often contribute to test validity such as whether the wordings of the questions were written in a clear and organized way. The panel of educators provided their feedback, and recommendation for brief modifications in the design, and the wording of some questions of the test. All suggestions offered by the panel of reviewers were incorporated in the final version of the questions. For example, the panel of reviewers suggested reformatting of the demographic information, restating some questions, and correcting spelling mistakes in some of the questions.

3.5.3 Establishing the reliability of TGS

A Pilot study was conducted for the purpose of assessing the consistency of the test through administering the test to a small sample of 10^{th} grade students. The pilot study provided evidence to look at the suitability of the test in terms of consistency and the time needed to complete the test as well as a general reference for procedures to enhance instrument administration with the main sample of the study.

In the pilot study, the questions were distributed to 20 10^{th} grade male and female students not participating in the main study. The aim of this pilot study was to establish the extent to which the questions can assess consistently what they were developed to assess. Following the administration of the questions to the pilot sample, the data collected were analyzed using SPSS to calculate the Cronbach's

alpha value. Internal consistency (reliability) of the instrument was found to be 0.72. An internal consistency coefficient (alpha) of 0.72 or higher is generally accepted as an indicator of acceptable reliability based suggestions offered by George and Mallery (2003), where ≥ 0.9 . Excellent, ≥ 0.8 . Good, ≥ 0.7 . Acceptable, ≤ 0.6. Questionable, ≥0.5 . Poor, and ≤ 0.5 . Unacceptable., p. 231).Therefore, the graphical literacy test GTS is considered reliable, and it can be considered a fair and precise measurement of graphical literacy. Following the reliability analysis, one item (item 3) was deleted to increase the reliability. The final version of the test therefore consisted of only 16 questions. **(See Appendix 1)**

3.6 Design

This study is exploratory survey design in which an attempt was made to explore student understanding of scientific graphs. The exploratory research is used in identifying a problem, and it helps in specifying the research design. Gay, Mills, and Airsian (2011) suggested that this type of research help in determining the data collection methods that are needed to answer exploratory research questions to establish understanding about existing phenomena.

3.7 Procedures

After the preparation of the test and logistical administrative issues, 150 copies of the test were distributed to private and public schools. A total of 125 were completed by students and prepared for marking. Exam papers were given to the science department in the school. Then the test was scheduled during a regular

science class, which took about 45 minutes. The science teacher supervised students during the test, and described all the test procedures.

3.8 Data Analysis

Collected responses were analyzed using SPSS software to establish statistical data appropriate to the research questions such as means, standards deviations, standard errors of measurement, t-test, and Pearson product correlation in order to answer the research questions. In response to the first research question, descriptive statistics means, standard deviations, and the range were used to present student responses to the test questions regarding graph interpretation and construction level exhibited by students. For research question 2, frequency distributions were used to help identify possible misconceptions possessed by 10^{th} grade students regarding the graphical literacy. The frequency distribution method provides quantification as to which option the students chose, and it specify in each question the frequency of students choosing the wrong options instead of the correct one. This strategy helps to quantify the level of misconceptions possessed by students. Furthermore, for research question 3 was answered by performing Pearson product moment correlation to identify any significant associations between the two aspects (interpretation and construction) of graphical literacy. Finally, research question 4 was answered using t-test to indicate any statistically significant differences between the performances of students based on their gender via comparing the means using independent t-test.

Chapter 4: Results

4.1 Overview

This chapter presents the analysis of the collected data in order to answer the research questions that are mainly concerned about the following:

1. What are the graphical skills of 10^{th} grade students?
2. What are the possible misconceptions possessed by 10^{th} grade students regarding the graphical literacy?
3. Is there any statistically significance association between 10^{th} grade student graphical literacy and their level of interpretation and construction?
4. Are there any statistically significant differences at ($\alpha \leq 0.05$) between the performances of students in graphical literacy that are attributed to student gender?

The chapter presents answers to the first question by identifying the graphical literacy of the 10^{th} grade students in particular their performance in both interpretation and construction skills that are measured in the TGS. In addition, this chapter describes possible misconceptions possessed by 10^{th} grade students regarding the graphical literacy. Furthermore, attempts were made to provide answers for question 3 and 4 by providing comparison of the graphical literacy at the level of interpretation and construction, and literacy according to student gender.

4.2 Q1: What are the graphical skills 10th grade students have?

Table 3: Means and Standard Deviation of Graph Interpretation

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Test Total Score	125	13.00	3.00	16.00	9.95	2.880
Total of Interpretation Questions	125	11.00	1.00	12.00	8.26	2.490
Total of Construction Questions	125	4.00	.00	4.00	1.69	.945

The graphical literacy skills at the levels of interpretation and construction were presented in Tables 3 above. The table shows that for the whole test, the mean score was 9.95 out of possible 16. The table also shows that when the questions were presented separately for each skill (i.e. interpretation and construction) students performed relatively better in the interpretation questions (M = 8.26) of a possible score = 12 compared to the construction questions (M = 1.69) of a possible score of (4). Overall scores are visualized in Fig. 1 below:

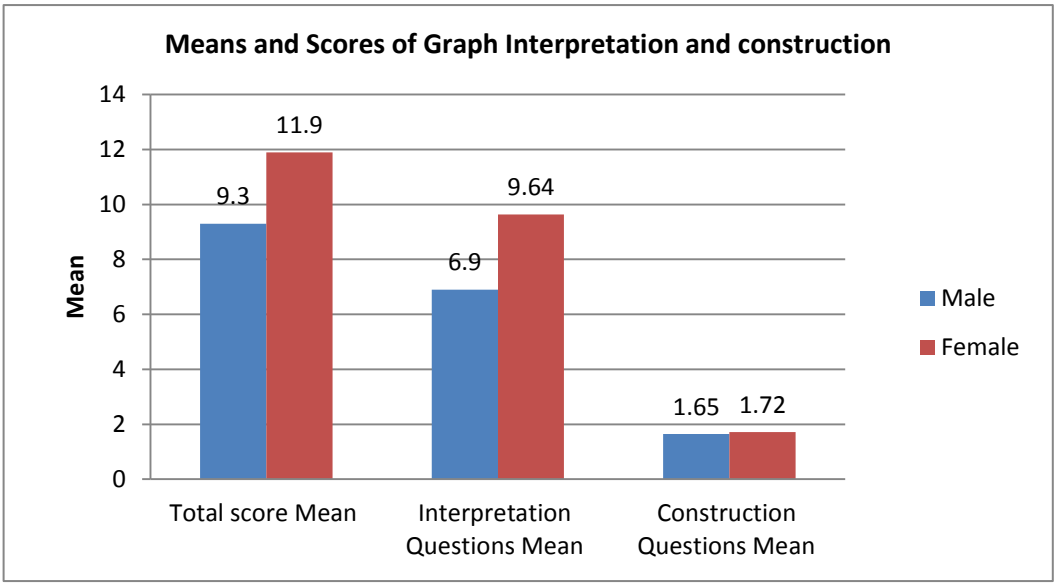

Figure 1: Means and Scores of Graph Interpretation and Construction

To further gain insights into student responses, questions related to each graphing skill were separately analyzed. Table 4 presents student responses to questions related to the skill of interpretation.

Table 4: Student Responses to Graph Interpretation Questions

Q	Student response N=125			
	Correct	%	wrong	%
2	102	81.60	23	18.40
5	117	93.60	8	6.40
8	100	80.00	25	20.00
9	101	80.80	24	19.20
10	24	19.20	101	80.80
11	105	84.00	20	16.00
12	86	68.80	39	31.20
13	104	83.20	21	16.80
14	49	39.20	76	60.80
15	49	39.20	76	60.80
16	105	84.00	20	16.00
17	91	72.80	34	27.20

As can be seen from Table 4, there are 12 items that examined different interpretation skills. Among the graphical interpretation the features assessed were reading key features of line and Pie charts,(Questions 2, 5, 8, 12, 16, &17), recognizing simple trends of line graphs (Question 3) , reading key features and recognizing physical knowledge of graphs (Questions 9, 11, & 13), and extracting

qualitative information from quantitative information and comparing information from two graphs (Questions 14 & 15).

Examination of the results presented in Table 4 suggest that student generally performed better in the interpretation with higher percentages of correct responses recorded for questions 2, 5, 9, 8, 11, 12, 13, 16, and 17, indicating that students were able to interpret key features of information presented in these graphs and recognize the properties of these graphs. On the other hand, questions 10, 14, and 15 were found to be the most challenging questions in the interpretation section, as only about 19.20% to 39.20% of the students managed to correctly answer these questions. These questions were designed to assess ability of students to extract qualitative information from quantitative information, and to compare information between two graphs.

Table 5 presents information on the questions that deal with graphical literacy related to the construction skill.

Table 5: Student Responses to Graph Construction Questions

Q	Student response N=125			
	Correct	%	Wrong	%
1	61	48.80	64	51.20
4	33	26.40	92	73.60
6	103	82.40	22	17.60
7	14	11.20	111	88.80

In regard to graph construction Table 5 showed that question 1 evaluated the skill of basic construction of tables and line graphs. In this question more than half of the students (51.20%) wrongly answered the question. Question 4 evaluated the skills of basic construction of a pie chart. In this question almost two third of the students wrongly answered this question, a result that may suggests weakness in this area of graph constructing. In addition, question 6 also evaluated the skills of basic construction of tables, graphs, and mathematical knowledge of a bar chart. This question was the easiest one as 82.40% of the student's answers were correct. Question 7 evaluated the skills of basic construction of tables, graphs, and mathematical knowledge of a bar chart. This question was the most challenging as 88.80% of students answers were wrong. Although questions 6 and 7 both measure students' ability to construct bar graph, the conceptual demands of the two questions are different. Question 6 evaluated student's ability to encode numerical data into bar graph, using mathematical prior knowledge of how to represent positive and negative numbers in the Y- X axis. While question 7 examined student's skills in plotting bar graph using physical prior knowledge of the relationship between gravitational force on the earth, and on the moon. Table 5 shows that students exhibit a relatively low knowledge of graph construction compared with graph interpretation.

4.3 Q2: What are the possible misconceptions possessed by 10th grade students regarding the graphical literacy?

Based on answers to the questions about the level of graphical literacy of 10th grade students at the interpretation and construction levels, a number of misconceptions about graph interpretation and construction emerged. Table 6 presents conceptual analyses to the misconceptions assessed by the questions.

Table 6: Conceptual Domains of Graph Interpretation and Their Associated Misconceptions

Concept	Misconception	Questions
Visual perception and graph recognition	1. Recognizing visual characteristics and basic features of a graph	2,8,10,12
	2. Relationship between variables	5,11,16,17
	3. Physical property of a graph	9,13
Reading multiple scientific graphs	4. Inferring and extracting graphical Information from multiple graphs	14,15

The test questions related to the graph interpretation focused mainly on two major conceptual domains which are the visual perception and/or graph recognition, and reading multiple graphs. The visual perception and/or graph recognition consist of the basic skills of graph reading including (1) recognizing visual characteristics, and basic features of a graph, (2) relationship between variables, and (3) physical property of a graph. Recognizing the visual characteristics, and basic features of a

graph, reflect that a student is able to identify x-y axes, identify the graph scale, and, identify x and y coordinates of a point. Table 6 shows that questions (2, 8, 10, and 12) assessed student's level in recognizing visual characteristics, and basic features of a graph whereas recognizing the relationship between variables was evaluated by questions (5,11,16, and 17). Recognizing the relationship between variables was defined as the ability of the student to identify whether an item is a constant or a variable, identify whether an item is a dependent or independent variable, and determine how variables are related to each other (Tonder, 2010).On the other hand, awareness of the graph's physical property, which denotes the ability to understand or consider a graph as a representational model rather than a typical picture or a map was assessed by questions 9 and 13. Previous research findings suggested that this is evident when students are not able to treat the graph as an abstract representation of relationships and consider it as a literal picture of a particular situation (Hadjidemetriou and Williams, 2002; Janvier,1998; Leinhardt,1990). For example when students were presented with a distance versus time graph consisting of increasing and decreasing lines they described the graph as something similar to "climbing a mountain", (Kerslake, 1981).

The ability to interpret multiple forms of graphs was also assessed using questions 14 and 15 of the graphing skill test. This form of graph interpretation focuses on the ability to extract information or infer them from multiple graphs. resul of the overall item analyses presented in Table 7, which reflect varying responses from students. Detailed analysis of these responses were presented in tables 8-11.

Table 7: Analysis of Student Responses to Interpretation Questions

Q	Concept Tested	Options			
		A	B	C	D
2	Reading key features from Line graph graphs	11.20	5.60	*81.60	1.60
5	Reading key features from Pie chart graphs	0.00	3.20	2.40	*94.40
8	Reading key features from Line graph graphs	4.00	9.70	*80.60	5.60
9	Reading key features from graphs, physics knowledge[Line graph]	1.90	*82.10	7.30	5.70
1	Basic reading of Tables ,graphs constructing, and mathematical operations.	19.50	3.30	*62.60	14.60
11	Reading key features from graphs, and physics knowledge.	3.20	4.80	* 84.70	7.30
12	Reading key features from Line graph graphs	12.80	11.20	*36.80	39.20
13	Reading key features from graphs, and knowledge of line graph	7.20	3.20	*83.20	5.60
14	Extracting qualitative information from quantitative information, and comparing information from two line graphs	12.80	11.20	36.80	*39.20
15		19.40	16.10	25.00	*39.50
16	Reading a simple trend in bar chart graphs	1.60	8.90	*85.40	4.10
17		5.70	13.90	5.70	*74.60

* Indicates correct answer of the question

Table 8: Recognizing Visual Characteristics and Basic Features of a Graph

Question	% of Wrong Answers
Q2	18.40
Q5	5.60
Q8	19.30
Q12	63.20
Q16	14.60
Q17	25.30

Table 8 describes percentages of students who demonstrated misconceptions related to visual perception, and graph recognition. In particular, recognizing visual characteristics and basic features of a graph. Question 2 was a line graph that evaluated student's ability to read basic information from graph, knowing the visual basics of a graph, and identifying x-y coordinates of a point plotted in graph. In question 2, 18.40 % of students were unable to correctly answer this question suggesting that they were unable to recognize the visual characteristics of the graph. Question 8 was also a line graph that examined student's level in reading basic information from the graph. As shown in Table 8, 19.30 % of the students lacked the skills of recognizing x-y axes, locating a point in the graph, and ability to extract information from the graph. In addition, question 12 was a line graph that studied student's capability to understand basic feature of graph. The percentage of wrong answers was 63.20%, which indicates that students have deficiency in the skills of

visual characteristics and basic features of a graph. Finally, questions (16, 17) were a bar graph that represents Food Source of Vitamin C in different elements. These questions examined student's ability to extract basic information from the graph. In question 16 only 14.60% wrongly answered the question, which shows students are lacking the concept of extracting basic information from the graph from a bar graph. Moreover, in question 17 (25.70%) of the students wrongly answered this question. Apparently students were unable to quote the correct information from the graph, as they couldn't relate the height of the bar with its value. Therefore students who wrongly answered the question were lacking basic skills of reading information from bar graph. Question 17 was a bar graph that represents the level of vitamin C in different food source, students were asked to read which food source has the lowest Vitamin C level. Most students opted for options A and C indicating inability to correctly relate the mathematical information along the Y axis to its correct position, resulting in choosing the wrong answer. Overall misconceptions related to visual perception, and graph recognition are visualized in Fig. 2 below:

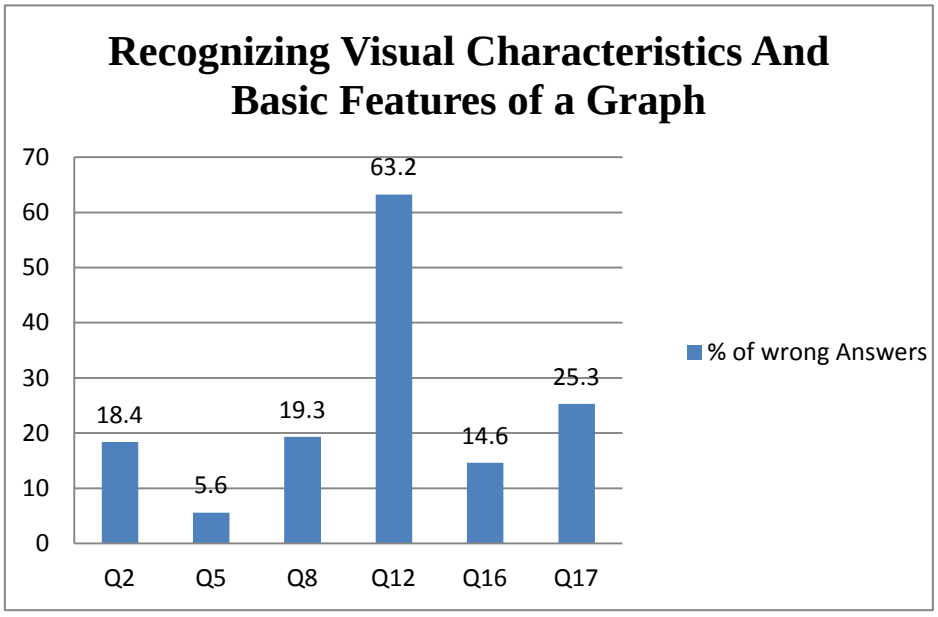

Figure 2: Misconceptions Related Recognizing Visual Characteristics and Basic Features of a Graph

Table 9: Relationship Between Variables

Question	% of wrong Answers
Q10	37.40
Q11	15.30

Visual perception of the graph was assessed by Q10 and Q11. Table 9 shows student conceptual problems with the visual perception, and graph recognition related to the relationship between variables. More than the third of students were unable to determine the dependent and independent variable, distinguish between constant and variable, relate variables to each other, and describe the nature of the relation between variables such as increasing, decreasing, and constant.

Q 11 was graphical representation of gravitational force acting on a balloon, and describes the relationship between all the forces acting on the balloon. Students were asked to figure out which is the gravitational force acted on the body. As presented in Table 9 above 15.30% of students was the percentage of the students who wrongly answered this question, suggesting that they were unable to recognize variables plotted in the graph. Misconceptions related to relationship between variables are visualized in Fig. 3 below:

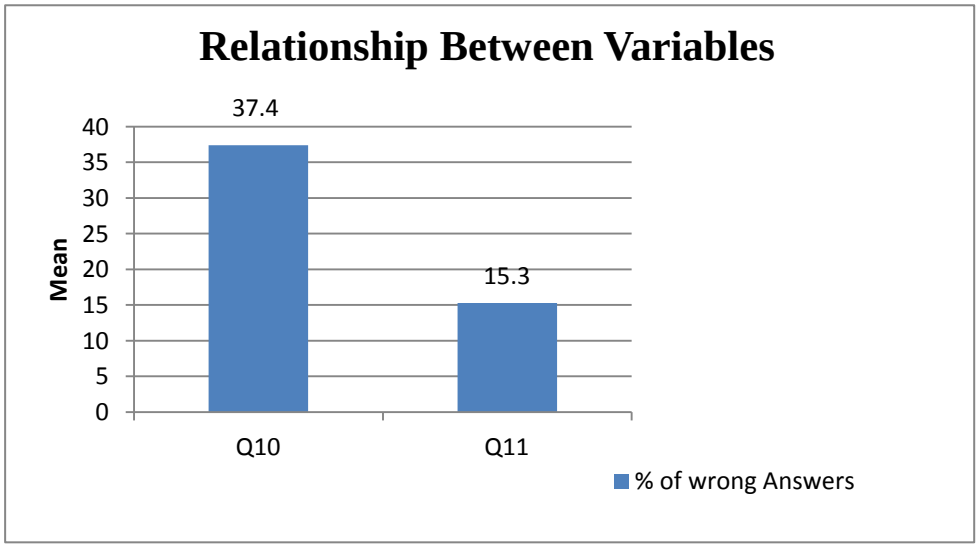

Figure 3: Misconceptions on Relationship Between Variables

Table 10: Student Response to Questions Related to Physical Property of a Graph

Question	% of Wrong Answers
Q9	14.90
Q13	16.00

Table 10 Shows the misconceptions related to understanding physical property of a graph. Questions 9 and 13 focused on measuring student's ability to read key features from a line graph, using physics knowledge. Question 9 was a line graph that describes motion of a cat and when this cat was at rest.14.90% of students wrongly answered this question, indicating that these students are lacking the needed skills to read a line graph , locating variables from the graph , relating dependent and independent variables , and concluding meaning of the numerical data represented in the graph. In addition, it indicates that students had the tendency to consider a graph as a typical picture or a map rather than a representational model. Question 13 on the other hand was a line graph that describes the motion of a ball. 16.00 % of the students answered this question wrongly, demonstrating that students have difficulty in recognizing the physical property of a line graph, and they were not able to treat the graph as an abstract representation of relationships. Graph misconceptions related to physical property of a graph are visualized in Fig. 4 below:

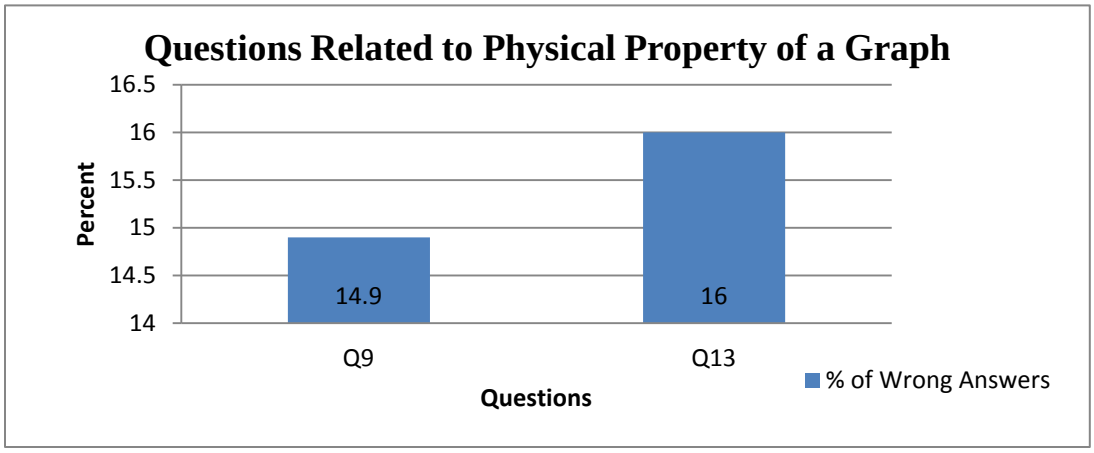

Figure 4: Graph Physical Property Misconceptions

Table 11:Inferring and Extracting Graphical Information from Multiple Graphs

Question	% of Wrong Answers
Q14	60.80
Q15	60.50

Table 11 shows the questions that evaluated students ability to infer and extract graphical information from more than one graph plotted in the same graph. In particular the questions focused on the ability to retrieve trends and draw conclusions from the graph. In both questions 14 and 15 more than 60% of the students were unable to infer and extract information from the graph, suggesting that students were having difficulties in the area of conceptual graphical literacy related to inferring and extracting information from multiple graphs. Misconceptions related to Inferring and Extracting Graphical Information From Multiple are visualized below:

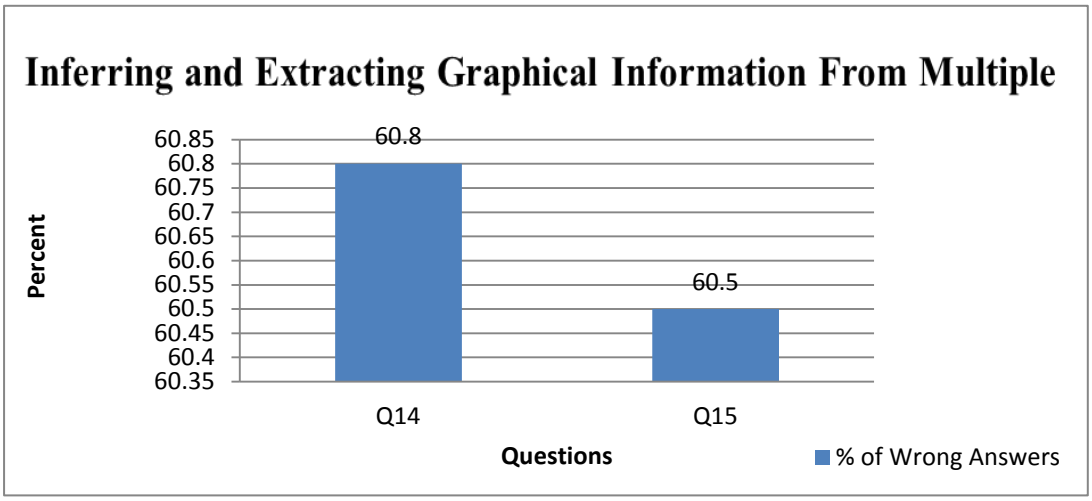

Figure 5: Inferring and Extracting Graphical Information from Multiple

Student misconceptions related to graph construction

Four questions (1, 4, 6, & 7) were used to evaluate student's abilities to construct graphs. These questions focused on encoding information into line, pie, and bar graphs. In each type of graph there are specific skills needed to construct the graph. According to Brasell (1990) in order to construct a line graph, the student should be capable of assigning dependent and independent variables to the correct axes, drawing and scaling axes, plotting points on a graph from data provided, and constructing a line of best fit. Moreover, for constructing a pie or a bar graph, prior knowledge of math is needed to create proportions of the represented data. In addition, for plotting bar graph, students should have the mathematical knowledge to represent discreet information, and understanding of how to plot negative and positive numbers. In Table 12, construction questions were grouped based on the skills needed to construct each graph.

Table 12: Conceptual Knowledge of Graph Construction

Concept	Misconception	Questions
Encoding Information into line.	• Assigning dependent and independent variables to the correct axes. • Drawing and Scaling axes • Plotting points on a graph from data provided • Constructing a line of best fit	Q1
Mathematical knowledge of graph construction	• Mathematical knowledge of pie graph construction. • Mathematical knowledge of bar graph construction.	Q4, Q6,Q7

Table 13: Analysis of Student Responses to Construction Questions

Q	Concept Tested	Options			
		A%	B%	C%	D%
Q1	Constructing of a line graph	*49.20	18.50	27.4	4.80
Q4	Constructing of , Pie chart.	27.70	*58.00	12.60	1.70
Q6	Constructing, and mathematical knowledge, of Bar chart	11.20	*82.40	4.80	1.60
Q7	Constructing, and mathematical knowledge, of Bar chart	*11.80	42.00	26.90	14.00

* Correct Response

Table 13 shows the frequencies of the selected response for each question.

Question 1 examined student's abilities to construct a line graph. As presented in Table 13, only 49.20 % of students correctly answered the question, with more than 50% were found to have alternative understanding which suggests the presence of misconception. Student's responses to question 1 reflected their misunderstanding in determining dependent and independent variables correctly, scaling the graph, locating variables in the graph, and creating best fit line graph. Only 49.20% were able to correctly recognize independent and dependent variables and scale the graph. The rest of the students exhibited misconceptions related to inability to scaling of graphs (option B and C) and plotting the points (Option D). Table 14, represents the calculated percentages that indicate the level of misconceptions in each question. Table 14 below summarizes the possible misconceptions in light of the percentage of the wrong answers in each question.

Table 14: Conceptual Difficulties Associated with Graph Construction

Misconception	Question	% of wrong answers
Encoding Information into a line graph (recognizing the variables, Y-X axes; and plotting points)	Q 1	50.70
	Q 4	42.00
Mathematical knowledge of graph construction	Q 6	17.60
	Q 7	83.20

Table 14 suggests that students have difficulties associated with the ability to encode information into graphs as over 50% of the student displayed alternative understanding of the concept of graph construction. Those students who selected the wrong answers lack the skills to construct a line graph.

Mathematical knowledge of graph construction necessitates that learners should use mathematical knowledge to figure out how to correctly draw graphs. Question 4 evaluated student's ability to use mathematical knowledge to construct a pie chart. As shown in Table 14, 42% of the respondents wrongly answered the question, demonstrating their deficiency in handling mathematical data and numbers and encoding them into pie graph. Similarly, Question 6, and 7 were concerned with assessing student's ability to construct bar chart. From Table 14, it can be said that 17.60% and 83.20% of students have selected the wrong answer for questions 6 and 7 respectively, suggesting that students were unable to use mathematical knowledge to handle numerical data and encode them into bar graph. Conceptual difficulties associated with graph construction are visualized in Fig. 6 below:

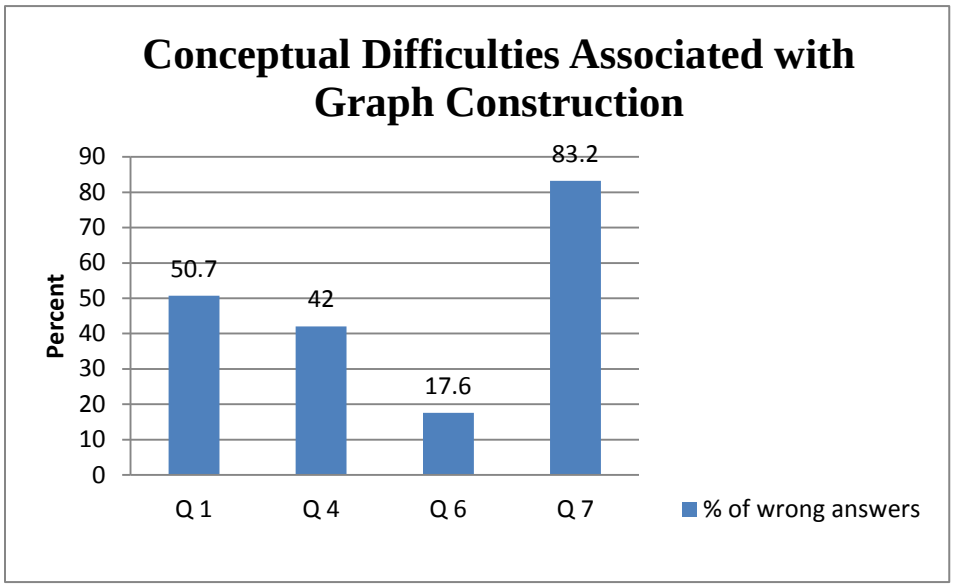

Figure 6: Conceptual Difficulties Associated With Graph Construction

4.4 Q3: Is there any statistically significant association between 10th grade student graphical literacy, their level of graph interpretation, and graph construction?

In order to answer the research questions about the possible significant association between student's ability to interpret and construct graphs, and their level of graphical literacy, Pearson correlation was performed to examine the association between student's ability to construct graphs, interpret graph, and their graphical literacy level.

Table 15: Correlation of Students' Graphical Literacy and Their Level of Interpretation and Construction

	Construction Total	Interpretation Total	Total Score
Mean	1.69	8.26	9.95
Interpretation Total	.25**	-	.95**
Construction Total	-	.25**	.54**
Total Score(graphical literacy)	.54**	.95**	-

**. $P \leq 0.001$).

As shown in the Table 15 significant correlation between the construction level and the interpretation level was found ($r = .25$, $n = 125$, $P \leq 0.05$). On the other hand, there is a positive significant correlation between the construction level and the total level ($r = .54$,$n = 125$, $P \leq 0.00$) indicating that knowledge of construction is closely associated with the graphical literacy, and this strong correlation between construction and the total signifies that the relationship of the knowledge of construction contribute more to understanding of graphs, and construction skill contribute more to graphical literacy of students than to interpretation. Likewise, interpretation also contributes to graphical literacy more than to construction skill

judging by the size of their. From the Table 15 above a strong positive correlation between the interpretation level and the graphical literacy level is concluded ($r = .95$, $n = 125$, $P \leq 0.00$). These findings suggest that both interpretation skills and construction skills are related to each other. Knowledge of interpretation can contribute to knowledge of construction, and also knowledge of construction can contribute to knowledge of interpretation.

4.5 Q4: Are there any statistically significant differences between the performances of students in graphical literacy that are attributed to student gender?

To answer the research questions related to testing the significant differences between students according to their gender, an independent-samples t-test was conducted to compare 10^{th} grade performances in graphical literacy.

Table 16: Summary of Statistics And T-Test Values of Students' Performance According to their Gender

Test	Gender	Mean	STD	t-value	Sig.
Total score	Male	9.30	2.77	-5.80	0.00
	Female	11.90	2.11		
Interpretation Questions	Male	6.90	2.49	-7.36	.00
	Female	9.64	1.57		
Construction Questions	Male	1.65	.83	-.44	.66
	Female	1.72	1.06		

As show in Table 16 significant differences in the overall total scores of males students (M = 9.30, SD = 2.77) and females students (M = 11.90, SD = 2.11) was found suggesting that females students have significantly outperformed their males counterparts ($t = 5.80$, $P \leq 0.000$).

Student responses to interpretation and construction items were also compared in terms of gender. Table 16 showed that there is no statistically significance difference between males and females students when it comes to constructing graphs. Both group of students managed to obtain low score in this area of graphical literacy (M=1.65, SD=.83 and M=1.73, SD=1.06) for male and female students respectively. However, a statistically significant difference between males and females with regard to male and female student's performance in graph

interpretation was observed (t =7. 37, P ≤ 0.000) in favor of females suggesting that female students once again performed significantly better than their males counterparts. Summary of statistics and t-test values of students' performance according to their gender are visualized in Fig. 7 below:

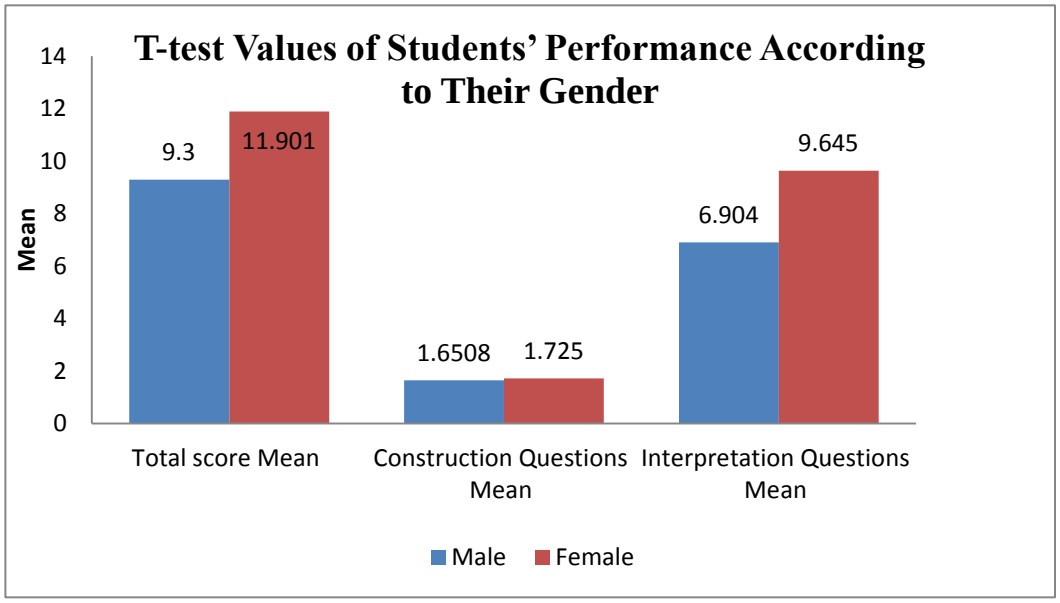

Figure 7: Summary of Statistics and T-test Values of Students' Performance According to their Gender

4.6 Summary

The purpose of this study was to investigate the graphical literacy of 10th grade students. This chapter presented the analysis of the four research questions and, they are : (1) What are the graphical skills 10th grade students have?, (2) What are the possible misconceptions possessed by 10th grade students regarding the graphical literacy?, (3) Is there any statistically significance association between 10th grade student graphical literacy and their level of interpretation and construction?, and (4)Are there any statistically significant differences between the performance

of students in graphical literacy that are attributed to student gender?. Different statistical approaches were used to analyze each question. Question 1 was analyzed using descriptive statistics means, standard deviations, and the range to present student's responses to the test questions regarding graph interpretation and construction level. The analysis of Question 2 using frequency distribution reflected that students generally performed better in graph interpretation than in graph construction. Moreover, the possible misconception analysis showed the misconceptions related to graph interpretation and, graph construction. Graph interpretation misconception domains were "visual perception" and "graph recognition", and "reading multiple Graphs". Furthermore, the graph construction misconception that were found are encoding information into a line graph, and mathematical knowledge of graph construction. Question 3 was analyzed using Pearson correlation, which indicates that there is a significance association between 10^{th} grade student graphical literacy and their level of graph interpretation, and graph construction. Finally question 4 were analyzed using Independent t-test, which indicated the following findings: (1) female students have significantly outperformed their males in graph literacy level, (2) there is no statistically significance difference between males and females students when it came to constructing graphs (3) , and female students performed significantly better than their males in graph interpretation.

Chapter 5: Discussion

5.1 Overview of the chapter

This chapter discusses the findings presented in chapter 4 within the context of the current literature. First the chapter presents discussion related to the research questions outlined in chapter 3, and provides attempts to propose recommendations for policy makers and curriculum planners. Also, suggestions for future research studies related to the concepts and the context of this study will be presented.

5.2 Q1: What are the graphical skills 10^{th} grade students have?

The findings indicated that generally 10^{th} grade students have deficiency in graphical literacy. Their performance in the assessed two main skills (interpretation and construction) varied, yet it showed better performance in interpretation rather than construction. The findings presented are similar to the findings described by (Bowen, and Roth 2005; Bulbul 2012; Kilic, Sezen, and Sari 2012; Kimura 1999; Leinhardt 1990; NCTM 2000; Tairab and Al Naqbi 2004; Uzun, Sezen 2012)

Uzun, Sezen, Bulbul (2012) reported similar findings that student's performance on interpreting tasks was found to be better than their performances on modeling and transforming tasks. He pointed out that students can read graphs and extract information from graphs but they have problems in constructing new graphs. This can be possibly due to the fact that interpretation is easier, while graph construction involves complex cognitive processes as the cognitive demand required

to construct graphs is much higher than those involved in interpretations (Tairab and AL Naqbi, 2004).

Leinhardt (1990) suggested that graph interpretation is easier than graph construction because modeling and transforming include building new graphs and constructing requires more competencies than interpreting. Tairab and Al Naqbi (2004) also reported that students found graph interpretation much easier than graph construction. However, other researchers showed that students experience more difficulties with graph interpretation when they have not been actively involved in data generation (Roth, 1996). On the other hand, Falk (1971) related graphical literacy development to Bloom's taxonomy levels. Falk (1971) suggested that a student should be able to construct graphs at the comprehension level and should be able to interpret graphs if he/she is operating at the application level.

The analysis of student's responses showed that many students can read and interpret key features of different types of graphs such as line, bar, pie graphs easily. The abilities to interpret key feature of scientific graphs were very clear in the basic reading questions that needed direct reading from the graph. As a result indicated that students were able to interpret key features of information presented in these graphs and recognize the properties of these graphs. Therefore, this can be classified as basic interpretation level. Beyond interpreting basic feature of scientific graphs, students apparently were unable to use complicated cognitive processes to solve the questions. In fact, they were able to locate answers directly from the graph (Table 5). Those findings are similar to Kimura's (1999) findings, which indicate that students

can extract qualitative information from quantitative information. Obviously they were able to extract trends, and describe relationship between variables when they were asked to interpret graphical information. Student ability to qualify information from the graph can be classified as higher level of graph interpretation (Kimura, 1999), which involve moderate cognitive abilities to solve the question. From this perspective it seems that these findings support the idea that students often use qualitative information to advance their interpretative graphical skills.

Furthermore, the findings of the present study support the NCTM's report stated that graph interpretation can be divided into three main levels: (1) elementary comprehension level which focuses on extracting specific data points from a graph. In this level, the desired information is explicitly represented in the graph and the graph reader is required only to locate and read the specific data point. (2) An intermediate level of understanding is characterized by finding trends and relationships in the data. (3) advanced comprehension level which requires extrapolation from the data and analysis of relationships expressed in the data such as generalizing to a population, making a prediction about an unknown, a comparison of trends and observing groupings. Elementary level is supported by the finding, as students can read and interpret key features of different types of graphs such as line, bar, pie graphs easily. Moreover, students can be classified as intermediate level, were they show ability to extract trends, and describe relationship between variables when they trying to interpret graphical information.

Difficulties associated with graph construction reported in the present study were also documented in previous research studies. Uzun, Sezen, Bulbul (2012) reported that students exhibited difficulties with graph construction. Their deficiency in construction of different types of graphs such as line, pie, and bar graphs was explained by the fact that students don't have enough skills to construct graph (Bowen, and, Roth, 2005). Kilic, Sezen, and Sari(2012) supported this findings, and indicated that students deficiency was due to their lacking of the needed skills. Students lack the strategies needed to make graph, such as understanding the purpose of plotting the graph, classifying the variables to be plotted, recognizing the relationship between the variables, and having needed prior knowledge for plotting a specific graph (Leinhardt,1990).

In the context of the present study, it seems that lack of systematic instruction is related to these findings. The limited emphasis of teaching graphs in the curriculum, and the lack of mastering the skills for interpreting and constructing different types of graphs have contributed to less mastering of the graphical skills. Kilic, Sezen, and Sari (2012) revealed in their study that the inadequacy of graphing skills extended to pre-service teachers, to reflect the fact that problems with graphical literacy is complex and extend beyond school children. This echo calls by science education researchers for increased attention to graphical instruction to help students become literate in practices related to the interpretation and, construction of graphs (Roth, 2002). Glazer (2011) suggested that besides the display characteristics of the graphs, peoples' knowledge of the content of graphs and their graphical skills

impact their interpretations of the data and it has a greater influence on novice graph viewers' interpretations.

The finding also showed that the interpretation process level can be classified according to the task requirements. Levels are varying, according to the complexity level involved in the task. Interpretation levels can be described as basic interpretation level which involve direct reading from the graph, intermediate level, which involve extract qualitative information and relating variables, and advanced interpretation level which, involve trends comparison, and derive conclusions (Kimura,1999; NCTM, 2000).

Difficulties in graph construction on the other hand were attributed to the fact that students do not have enough skills to construct graph (Bowen and Roth, 2005).

5.3 Q2: What are the possible misconceptions possessed by 10th grade students regarding the graphical literacy?

The findings presented in chapter 4 showed that students possessed a number of misconceptions related to the development of the concepts of interpretations and construction of scientific graphs. These findings are similar to the findings described in previous research studies (Friel, Curcio, and Bright 2001; Hadjidemetriou and Williams 2002; Janvier 1998; Kerslake 1981; Leinhardt, Zaslavsky, and Stein 1990; Padilla 1986; Shah, and Heffner 2002; Tairab and Al Naqbi 2004; Kali 2005; Tonder 2010; Uzun, Sezen, Bulbul ,2012).

The findings of this study revealed that the students have difficulties related to graph interpreting and graph constructing. Apparently they exhibited misconceptions related to visual perception and graph recognition, which focuses on (1) Recognizing visual characteristics and basic features of a graph, (2) Relationship between variables, and (3) Physical property of a graph.

In addition, this study revealed that students have misconception on reading multiple graphs which involve inferring and extracting graphical information from multiple graphs. The study findings reflect that students were unable to read the graph correctly, and this is attributed to their inability to recognize basic features of a graph, such as identifying x-y axes, graph scale, and identifying x and y coordinates of a point. Leinhardt, Zaslavsky, and Stein (1990) used the term misconceptions to classify students' difficulties in graph interpretation. Leinhardt, Zaslavsky, and Stein (1990) reported that students exhibited inability to relate variables to each other, identify whether an item is a constant or a variable, identify whether an item is a dependent or independent variable, and determine how variables are related to each other. The findings reported in the present study seem to support those reported by (Leinhardt, Zaslavsky, and Stein, 1990). Tonder (2010) stated that problems with graph comprehension identified were: finding ratios between data; identifying dependent and independent variables; interpreting slope and height changes on a curved graph; identifying and interpreting scale; using a second y-axis and multiple sources of information; working with reciprocal values of data; and extracting information from a graph without first critically examining the y-axis (zoom

graph‘confusion). Students also did not incorporate their own prior knowledge or understanding into the construction of reasonable responses; instead they stated relationships in the data or incorporated creativity. The findings of the present study clearly showed that students were unable to understand physical property of graph as described in Table 10. In order for students to realize physical property, they need to consider a graph as a representational model rather than a typical picture or a map. Apparently students were unable to apply graphical interpretation skills correctly because they just looked at the graph and considered it as a without considering the actual representation of the graph, and how variables are related to each other. These findings therefore support previous research findings that suggest students are not able to treat scientific graphs as an abstract representation of relationships and consider it as a literal picture of a particular situation (Glazer 2011; Hadjidemetriou and Williams 2002; Janvier 1998; Kerslake, 1981; Leinhardt 1990). Kerslake (1981) claimed that when students were presented with a distance versus time graph consisting of increasing and decreasing lines they described the graph as something similar to “climbing a mountain”.

Glazer (2011) showed in his review of literature about challenges with graph interpretation that in science and mathematics curricula, graphs are distinguished for their difficulties. Glazer (2011) stated the following problems are often encountered by students when dealing with scientific graphs: (1) confusing the slope and the height; (2) confusing an interval and a point;(3) considering a graph as a picture or a map; (4)conceiving a graph as constructed of discrete points; (5) constructing an

understanding of graphs presented during classes appears to be a particularly difficult task; (6) the tendency to sketch graphs that always pass through the (0,0) point; (7) the amount of information that is presented in the graph, which means the complexity of the presented information presented in a graph can also influence graph reading performance and comprehension. The number of variables, such as the number of lines displayed in a line graph, the number of trend reversals in a line (i.e., the up and down vacillations of one line), and the number of individual data points influence interpretations of graphs (Carpenter and Shah, 1998); (8) difficulties with graph interpretation that result from inappropriate choice of graph format or visual features such as color, size, aspect ratio, scale and legend/labels; (9) an emphasis on x-y trend might lead to incomplete interpretation; (10) difficulties with interpretation of complex line graphs such as those of three dimensional graphs or those that require a series comparison; and (11) teachers' experience with teaching scientific graphs that might be a barrier to the implementation of meaningful practice in graphing competence (Glazer, 2011). Kali (2005) reported that students have graph interpretation difficulties relayed to how to determine coordinates and describe relationships. Furthermore, Kali (2005) found that students have difficulties in reading and interpreting data from multiple graphs. Interpretation of multiple graph as reported in Table 11 found to be the most challenging tasks. This deficiency can be explained by the complexity of reading the data, reading between the data, and reading beyond the data. Shah and Heffner (2002) claimed that the x–y trends can

lead to incomplete interpretations of data when the data are complex (for example, multiple lines on a display representing a third variable.

The difficulties with interpretation may very well be explained by the fact that students lack the needed strategies to read graphs correctly such as understanding the context of the problem, and lacking the prior knowledge of the different forms and types of graphs. Tairab and Al Naqbi (2004) stated that deficiency in graph reading can be attributed to student's inability to read graphs in the proper way. Friel, Curcio, and Bright (2001) identified three main components of graph comprehension that showed progression of attention from local to global features of a graph: (a) To read information directly from a graph, one must understand the conventions of graph design; (b) to manipulate the information read from a graph, one makes comparisons and performs computations; and (c) to generalize, predict, or identify trends, one must relate the information in the graph to the context of the situation (Friel, Curcio, and Bright, 2001).

The findings reported in the present study found that misconceptions of Graph construction were related to how to encode information into different graph format such as : (1) Assigning dependent and independent variables to the correct axes; (2) Drawing and Scaling axes; (3) Plotting points on a graph from data provided; and (4) Constructing a line of best fit. Difficulties in modeling and transforming data into graph may be explained by the fact that students were unable to assign variables to the proper axis, and to plot data correctly (Uzun, Sezen, and Bulbul ,2012).

Furthermore, students showed difficulties in constructing different types of graph, and modeling data into line graph , bar graphs, and pie graphs. They were also unable to decide independent and dependent variables, and to assign them correctly in their axes. Furthermore, the inability to encode information is also related to the inability of drawing, scaling, and plotting points correctly. Padilla (1986) examined the line graphing ability of middle and high school students and found that out of the 625 students tested only 46% could correctly assign the variables.

These findings were similar to those reported by Tairab and Al-Naqbi (2004) that some students could not see the relationship between the dependent and independent variables and how they should be plotted on the axes.

The present study may explain the difficulties students have in constructing graphs in relation to the lack of prior mathematical knowledge to handle numerical data and encode them into graphs. In particular the ability to manipulate negative and positive numbers, and assign them correctly in the right axes. Based on this findings, it can be generalized that student prior knowledge about graph content, graphing skills, and the related subject matter content may influence graph reading as well as graph construction.

Kali (2005) in his review of literature described a number of studies that identified problems in constructing graphs, by both secondary and tertiary level

students (Berg and Phillips, 1994; Berg and Smith, 1994; Brasell and Rowe, 1993; McDermott 1987; Mevarech & Kramarsky, 1997 Padilla 1986;).

In summary, the findings of the present study seem to be in line with most of the previous findings that students often experience difficulties with understanding scientific graphs. Difficulties are often described in terms of inability to recognize variables in scientific graphs, and inability to determine how variables are related to each other. Also, inability to identify ratios between data, interpreting slope and height changes on a curved graph; identifying and interpreting scale; using a second y-axis and multiple sources of information; working with reciprocal values of data; and extracting information from a graph without first critically examining the y-axis (zoom graph‘ confusion). It is clear that the findings are also pointing to the fact that students did not incorporate their own prior knowledge or understanding into the construction of reasonable responses; instead they stated relationships in the data or incorporated answers from their own imagination.

5.4 Q3: Is there any significance relation between 10th grade student graphical literacy and their level of interpretation and construction?

The findings of the present study in regard to the graph interpretation and construction showed that there was a statistically significant correlation between the ability of the students to construct and their ability to interpret graphical information. The findings also showed significant correlations between both interpretation and construction abilities , and the overall graphical literacy level.

These findings suggest that knowledge of graph interpretation is more likely to influence knowledge of graph construction. If students master skills of interpreting graph it is likely that it will help their effort to construct and transform graphical information. Mevarech and, Kramarsky (1997) described that graphing involves both interpretation and construction, and that they are interrelated process. With regard to the association between construction and interpretation of graphical information on one hand and their overall graphical literacy, Leinhardt, Zaslavsky, and Stein (1990) described the relationship between graph interpretation and, construction. They noted that interpretation does not require any construction, construction often builds on some kind of interpretation. In addition, If students have enough skills to construct such as recognizing X-Y axis, relation between dependent and, indent variable, plotting coordinates, correctly scale the graph; the interpretation and reading basic information from the graph will be easy for them .

5.5 Q4: Is there any association with 10th grade graphical literacy and gender?

The findings of this question suggested both male and female student performed moderately in the graphical skill tests. Furthermore, female students significantly outperformed their males in graph literacy level, showing better understanding and less misconceptions in the interpretation of graphs. However, there were no statistically significant differences between males and females students when it comes to construction of graphs.

The findings reported in the present study showed that female students significantly outperformed their males counterparts in their overall graphical literacy performance and graph interpretation level, as described in Table 16. These findings are similar to other findings such as those described by TIMSS (2011) and, Lowrie, and Diezmann (2009). TIMSS (2011) revealed that there were significant differences in the average science scores of males and females of UAE student's science performance, although these differences were not in graphical literacy alone. Lowrie, and Diezmann (2009) on the other hand reported that boys outperformed girls on complex levels of graphical decoding. However, the present study found that there were no differences between male and female students in regard to graph construction performance. Apparently both groups managed to have low performance in graph construction due to the lack cognitive abilities and skills needed to construct graphs among both group of students. As mentioned previously graph construction requires the presence of these cognitive abilities and the skills to conceptualize information depicted in data and transform them into graphical

information. Although the finding pointed to differences between boys and girls, more researches are needed to specifically isolate the source of differences in performance.

5.6 Implications for Practice:

Graphs recently become a part of our daily practices because of their use in all media such as newspapers, magazines, medical report, and etc. Furthermore, graphs are powerful tools to represent and summarize information in easy readable visual representation. Graphs are effective tool for data summarization, and trends verification. However, the process of analyzing graphical data and communicating meanings represented in the graph are considered intellectual scientific skills. Therefore, the findings reported in the present study have educational implications for curriculum planners and developers, science teachers, and students. The development of any plan that focus on graphic literacy instruction through integrating these skills in the curriculum, or by focusing on teachers professional development activities so that they become able to deliver the significance knowledge about graphs. The study highlighted student's difficulties and deficiency in graph interpretation and construction that need to be taken into consideration when reviewing and developing science curricular. Science curriculum developers need to consider the levels of graphical literacy of students in the curriculum to enhance and improve student's graphical literacy. Moreover specific professional

development plans may need to be developed and implemented to help science teachers to better understand how students deal with and develop graphical literacy.

5.7 Recommendation for the future studies:

Based on the findings reported in the present study, more research studies are needed to further explore student's difficulties with graphical skills and how graphical literacy is developed by students. The following recommendation can therefore be suggested.

Research studies that explore graphical skills included in the science curricular, and how is integrated to help students develop their graphical literacy.

- In order to gain detailed insights into explanations for the performance differences in graphical literacy exhibited by males and females in this study, the identification and addition of more items that reveal performance differences would strengthen the present study.
- Research studies related to how teachers deal with the graphical skills in earlier stages in the schools are needed to establish knowledge base of students in relation to graphical literacy.
- Science teacher's graphical literacy level can also be investigated to make sure that intended curricular goals are implemented.

- Additional research studies could be conducted to investigate the effects of different teaching methods and learning environments on students' ability to interpret and construct graphs.

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Appendices

Appendix A: Test of Graphing skills (TGS)

Appendix B: اختبار مهارات الرسومات البيانية

Test of Graphing Skills (TGS)

Instructions for students who will take this test:

The Test of Graphing skills (TGS) is made up of three parts, student's demographic information, test questions, and survey
Read the entire question carefully, and then select the appropriate answer
Don't select more than one answer
The test consists of 13 pages and 16 questions
The time for the exam is one hour
You may use the calculator if you wish to do so
Attempt all the three parts of this test

Student's Name:_____ **Gender:** _____

Nationality : UAE National ☐ Non-UAE National ☐

Type of school : Public ☐ Private ☐

Effective language : Arabic ☐ English ☐

Part 1: Demographic Information

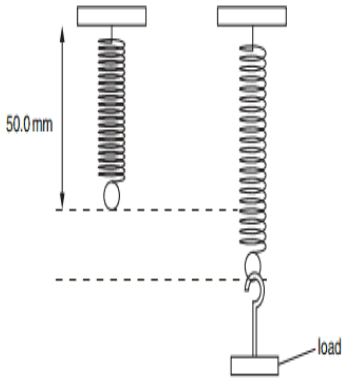
Part 2: (Test Questions)

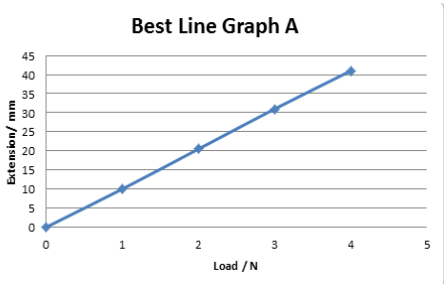
***Draw a circle around the letter that you think represents the correct answer*.**

Q1: A stretched spring of overall length 50.0 mm is hung from a support, as shown in figure below. Different loads are placed on the spring and the extension is measured each time. Using the values of the loads, and the measured extension, which of the following graphs will probably be the best line graphs?

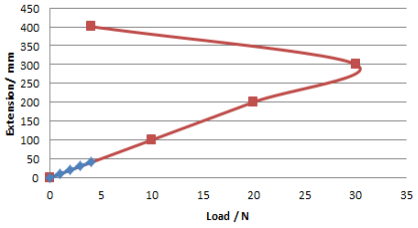
The extension for the different load are given in the table below

Load /N	Extension /mm
0.0	0.0
1.0	10.0
2.0	20.5
3.0	31.0
4.0	41.0

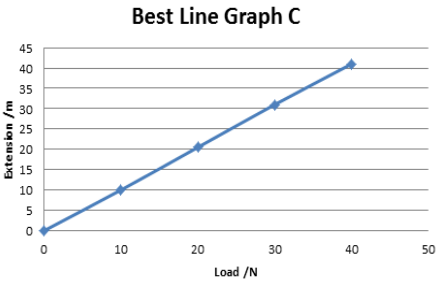




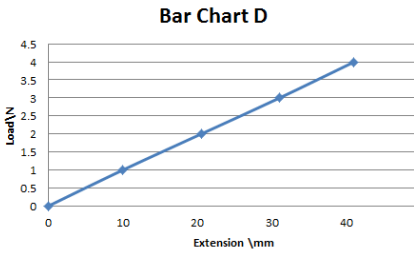
A.



B.

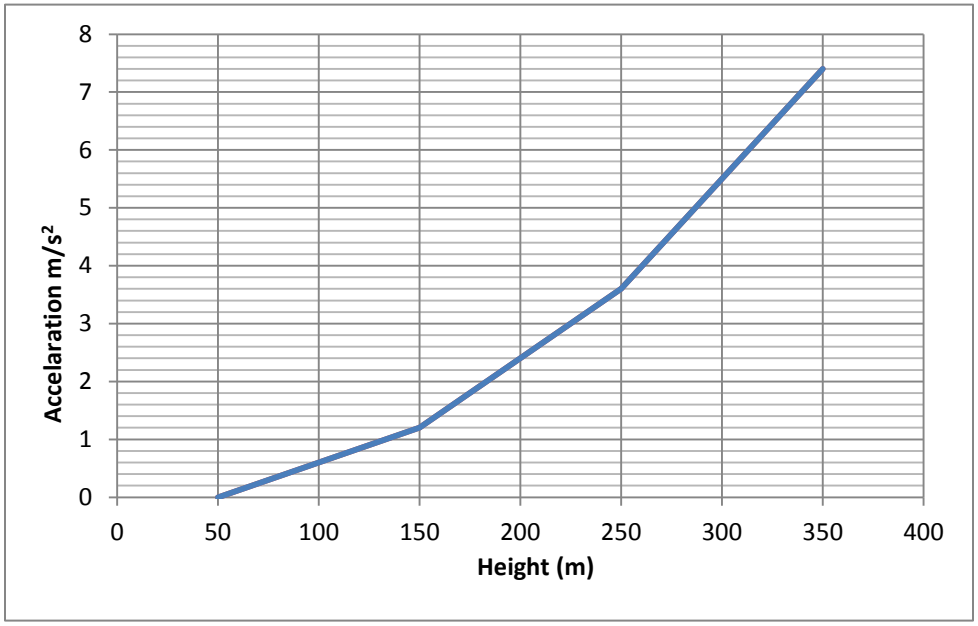


C.



D.

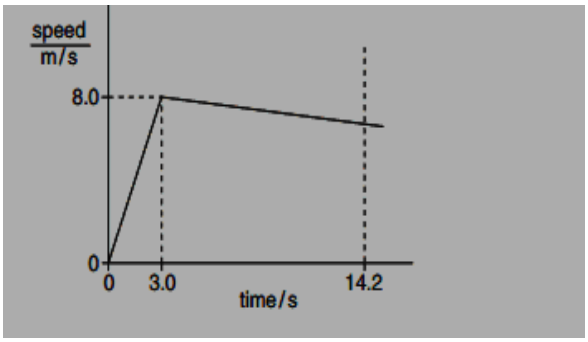
Q2: The plot below describes the acceleration (increase in speed) of the skier at various heights above the bottom of the hill.



The acceleration of the skier at the height of 350 is ----------

a. 6.2 m/s^2 b. 7.0 m/s^2 c. 7.4 m/s^2 d. 4.2 m/s^2

Q3: A young athlete has a mass of 42 kg on a day when there is no wind, she runs a 100 m race in 14.2s the sketched graphs below (not to scale) shows her speed during the race

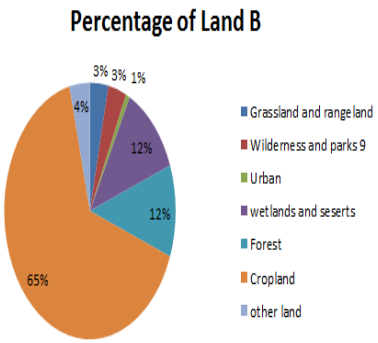


- **The acceleration of the athlete during the first 3 seconds is?**

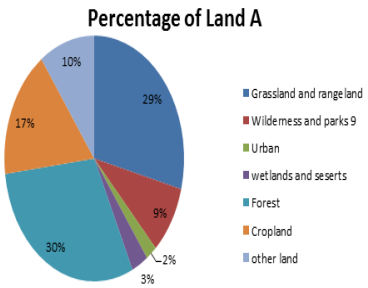
a. **0.37** m/s^2 b. **0** m/s^2 c. **24** m/s^2 d. **2.7** m/s^2

Q4: Which of the following pie chart below represent information in the table of land and percentage table?

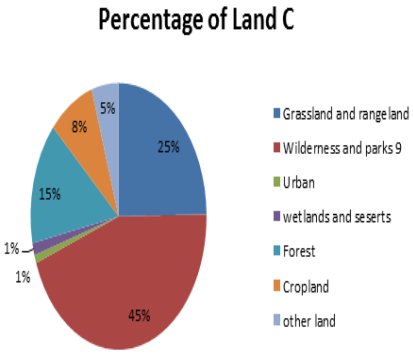
Kind of Land Use	Percentage of Land
Grassland and rangeland	29
Wilderness and parks 9	9
Urban	2
wetlands and seserts	3
Forest	30
Cropland	17
other land	10



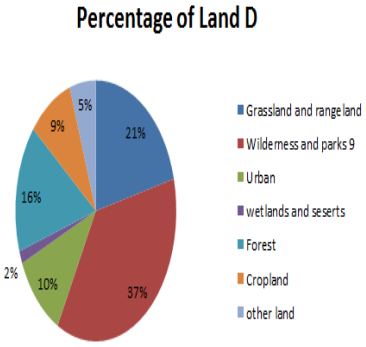
A.



B.

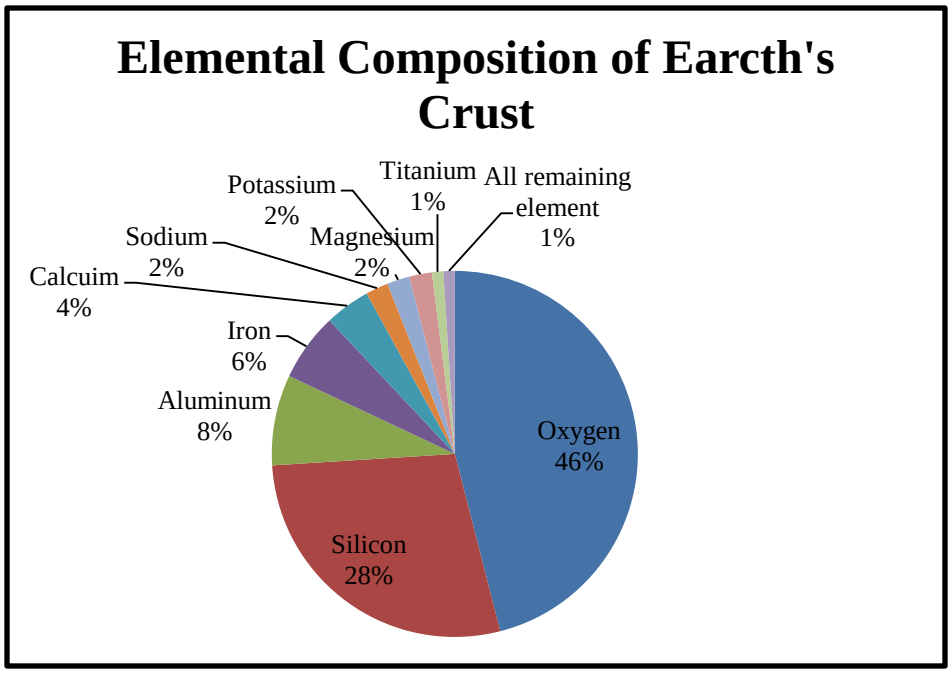


C.



D.

Q5: The pie graph below represent the composition of the Earth‘s Crust:



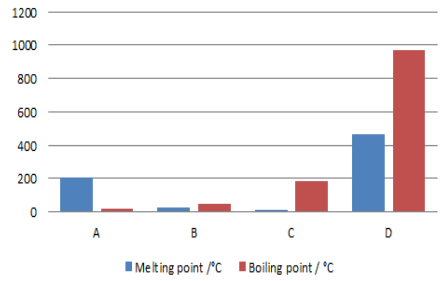
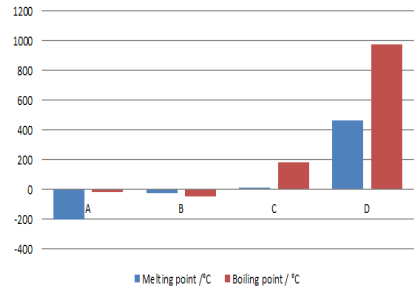
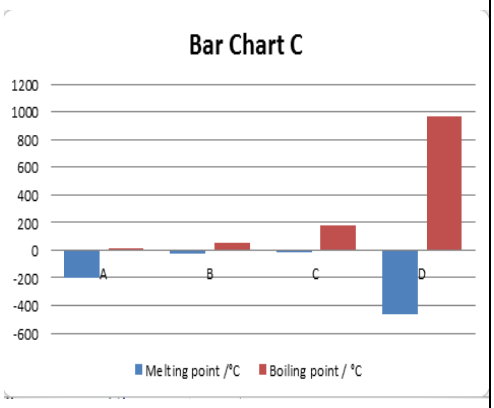
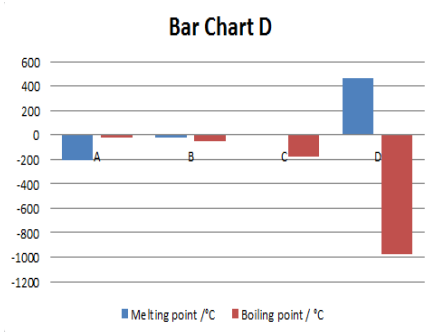
- **The percentage of the Magnesium Elements in the Earth’s Crust is?**

A. 46% **B. 28%** **C. 1%** **D. 2%**

Q6: The table below shows the melting points and boiling points of four substances:

Substance	Melting point /°C	Boiling point / °C
A	-203	-17
B	-25	-50
C	11	181
D	463	972

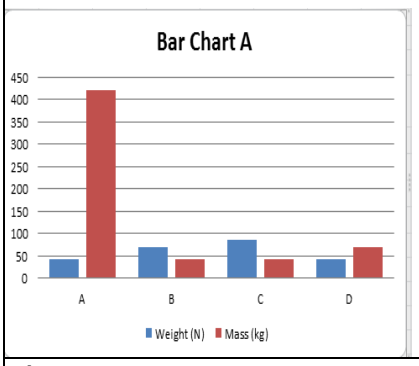
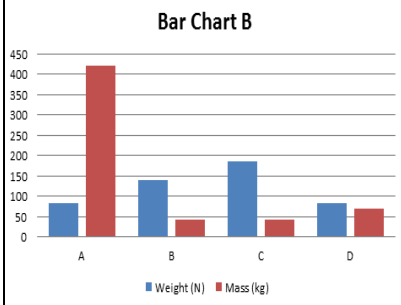
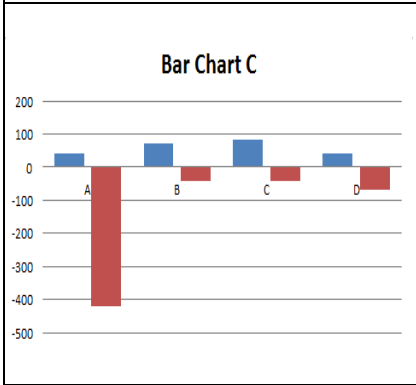
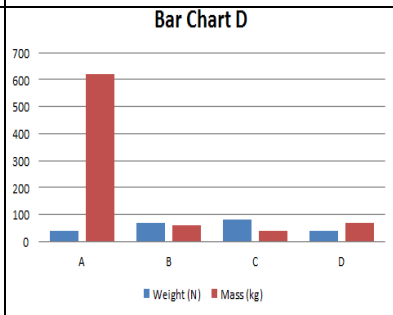
Which of the following graph represent the information in the table?

<table>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>A.</td><td>B.</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>C.</td><td>D.</td></tr>
</table>

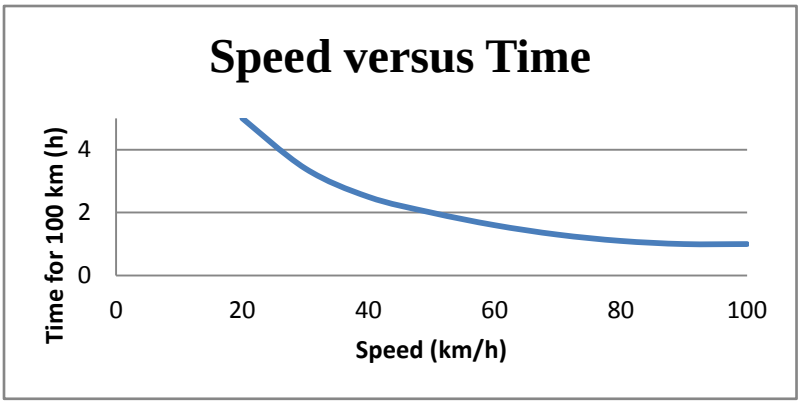
Q7: The table shows the mass and weight of objects on Earth. What is the mass and weight of the objects on the moon, if the moon's gravitational attraction is one sixth that of earth?.

Objects	Weight (N)	Mass (kg)
A	42	420
B	70	42
C	84	42
D	42	70

Which of the following is the bar graph that represents the weight and the mass of the objects in the moon?

<table>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>A.</td><td>B.</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>C.</td><td>D.</td></tr>
</table>

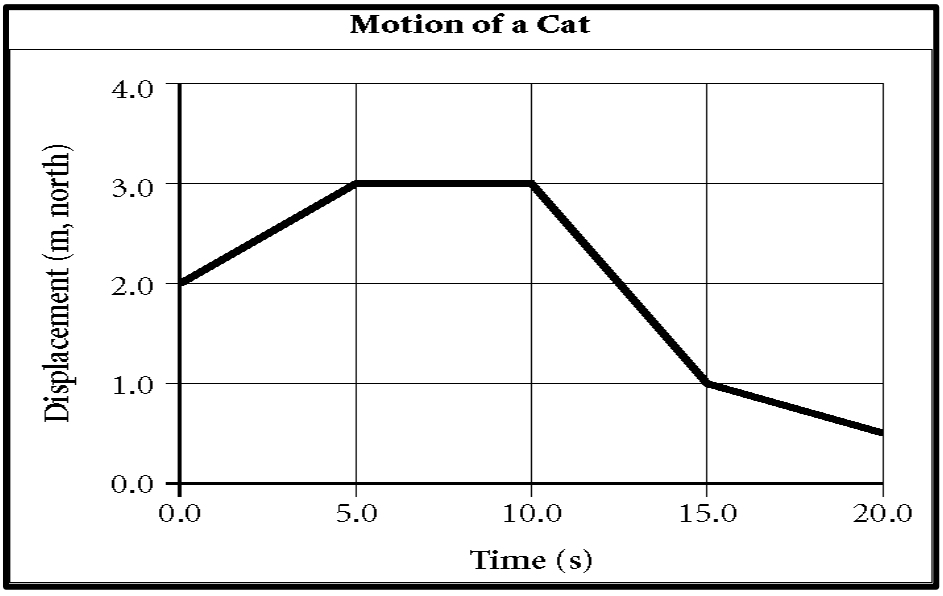
Q8: The time required to make a trip of 100.0 km is measured at various speeds according to the graph below:



- **What speed will allow the trip to be made in 2 hours?**

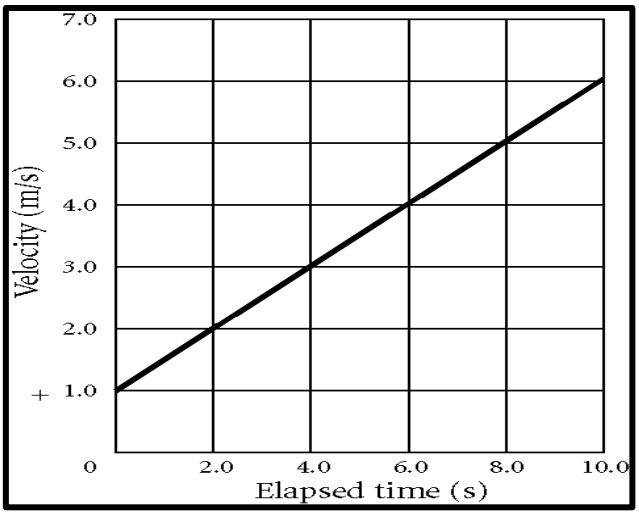
A. 20.0 km/h **B.** 40.0 km/h **C.** 50.0 km/h **D.** 90.0 km/h

Q9: According to the graph below, during which interval is the cat at rest?



A. 0.0–5.0 s **B.** 5.0–10.0 s **C.** 10.0–15.0 s **D.** 15.0–20.0 s

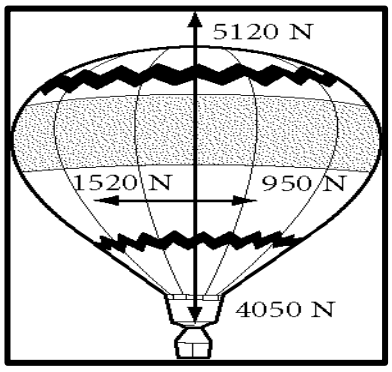
Q10: The graph below describes the motion of a cyclist:



- **The acceleration of the cyclist is ----------**

A. constant **B.** Decreasing **C.** Increasing **D.** zero

Q11: In the free-body diagram shown below:

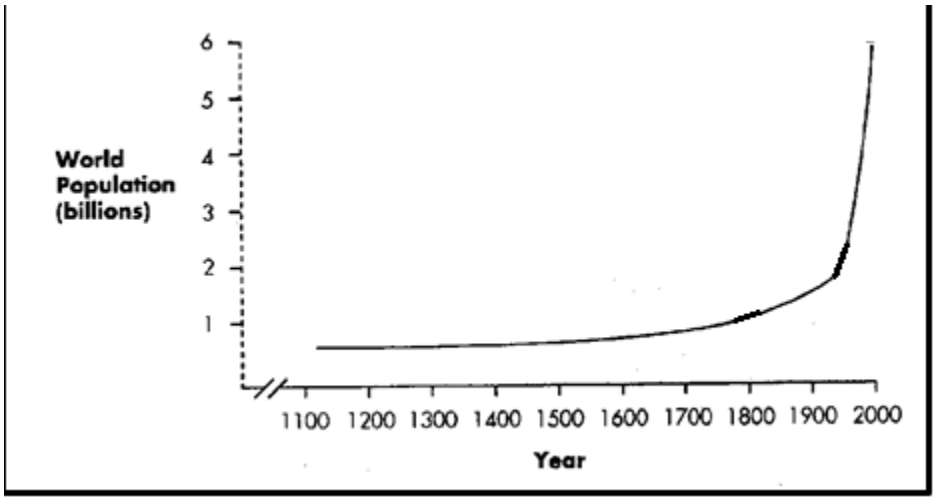


- **Which of the following is the gravitational force acting on the balloon?**

A. 1520 N B. 950 N C. 4050 N D. 5120 N

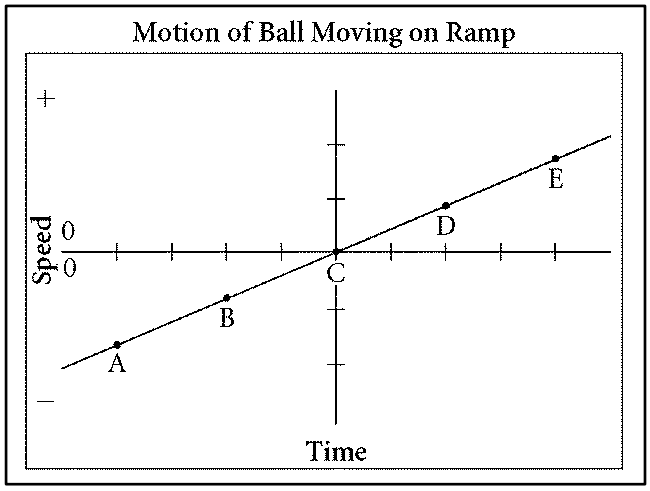
Q12: The graph below shows the world population in (billions) against time, what is the population during 17 century (1800)

World Population Growth



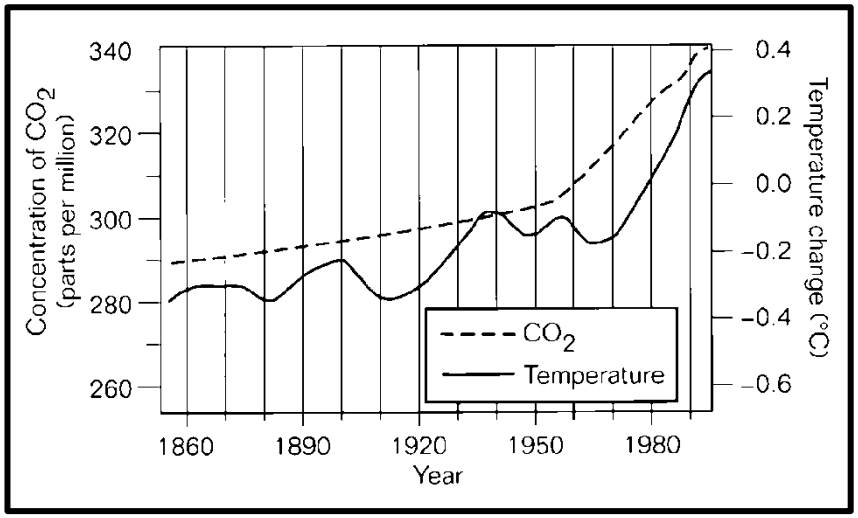
A. 500 thousand **B.** 1 million **C.** 1 billion **D.** 2 billion

Q13: The graph below describes the motion of a ball. At what point does the ball have an instantaneous velocity of zero?



A. A B. B C. C D. D

Q14 and Q15 related to the graph below.



Q14: The conclusion drawn from the graph is

A. The concentration of CO_2 in the atmosphere from 1860 to 1995.

B. The change in average global temperature since 1995.

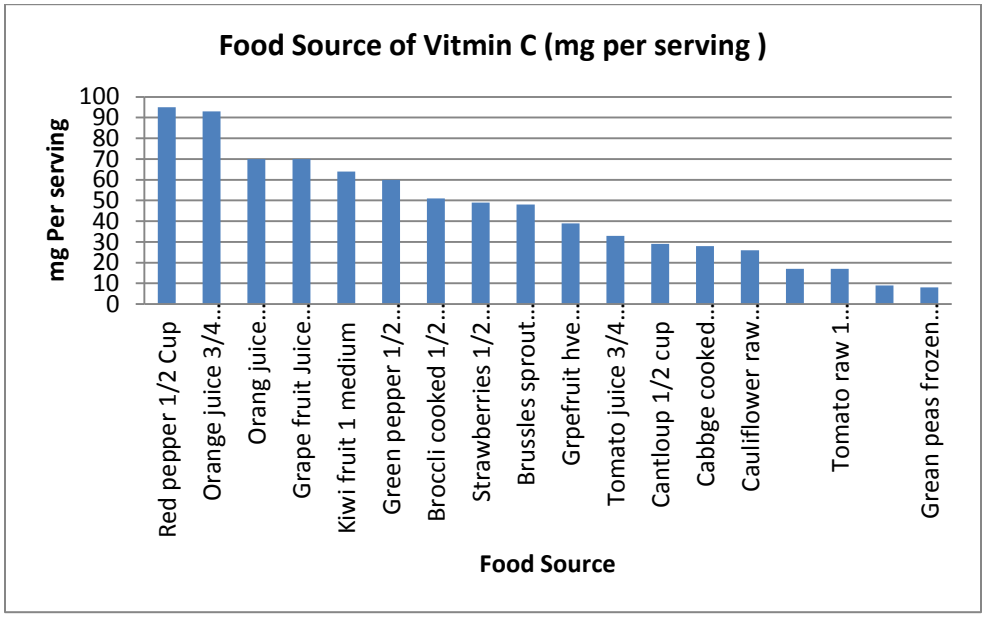
C. That the concentration of oxygen in the atmosphere has increased since 1860.

D. That global warming is linked to the greenhouse effect.

Q15: Refer to the illustration above. According to the graph,

A. From 1900 to 1950, the average global temperature constantly increased.
B. The concentration of CO_2 in the atmosphere increased at the same steady rate from 1920 to 1980.
C. The concentration of CO_2 and the temperature were the same in 1900.
D. CO_2 in the atmosphere and temperature have increased since 1980.

Q16 and Q17 belongs to the following graph:



Q 16: What is the highest value of vitamin C level?

A. 89 B. 50 C. 93 D. 90

Q 17: Which food source has the lowest Vitamin C level ?

A. Red pepper ½

B. Spinach cooked ½ cup

C. Tomato Raw 1 medium cup

D. Green Peas frozen

اختبار مهارات الرسومات البيانية

تعليمات للطلبة الخاضعين لهذا الاختبار:

1.اختبار مهارات الرسومات البيانية يتكون من ثلاث أجزاء :

ا.البيانات الدموغرافية للطالب
ب.اسئلة الاختبار
ج.استبان

2.اقرأ السؤال بتمعن واختر الإجابة الأنسب .

3.لا تختار أكثر من إجابة.

4.الاختبار يتكون من 13 صفحة و 16 سؤال .

5.مدة الاختبار ساعة واحدة .

6.يمكن استخدام الآلة الحاسبة اذا شاء الطالب.

7.يرجى الإجابة على أجزاء الاختبار الثلاثة.

الجزء الأول :البيانات الدموغرافية

اسم الطالب : _____

الجنس: ذكر ☐ أنثى ☐

الجنسية: اماراتي الجنسية ☐ غير اماراتي ☐

نوع المدرسة: حكومية ☐ خاصة ☐

اللغة: عربي ☐ انجليزي ☐

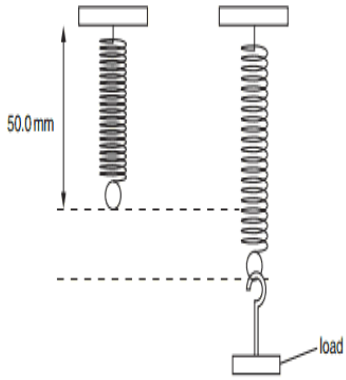
الجزء الثاني : (اسئلة الاختبار)

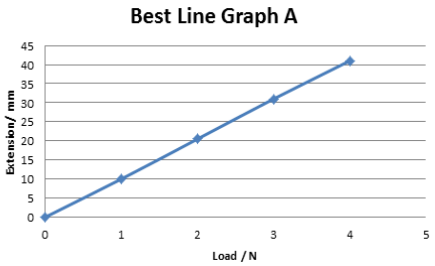
ضع دائرة حول الحرف المقابل للإجابة الأنسب

السؤال1 :زنبرك مشدود طوله الإجمالي 50 مليمتر علق على قاعدة كما هو مبين في الصورة.تم وضع أثقال مختلفة الوزن و تم قياس طول امتداد الزنبرك في كل مرة.باستخدام قيم الأوزان وقياس امتداد الزنبرك أي من الرسومات البيانية الخطية(**Line graph**)التالية يمثل علاقة الوزن المعلق بطول امتداد الزنبرك

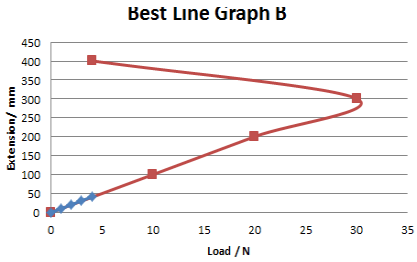
طول امتداد الزنبرك لعدة أثقال مبين في الجدول التالي

Load /N	Extension /mm
0.0	0.0
1.0	10.0
2.0	20.5
3.0	31.0
4.0	41.0

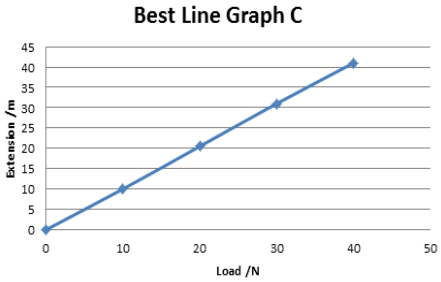




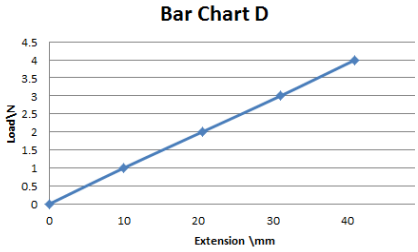
A.



B.

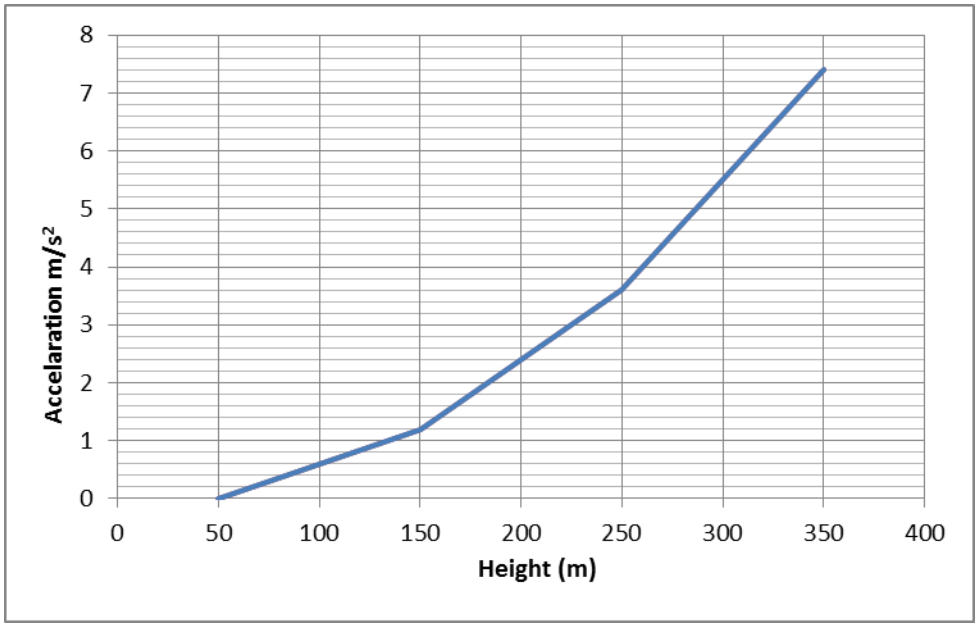


C.



D.

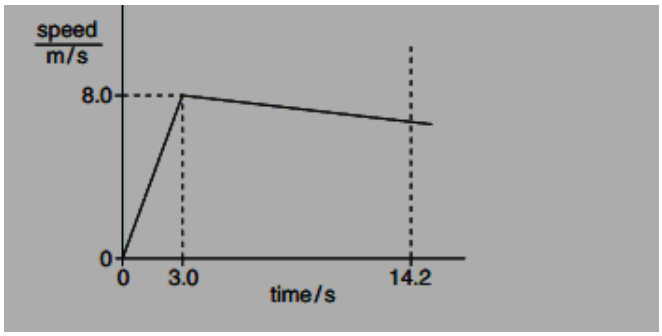
السؤال 2: الرسم البياني التالي يصف العجلة (الزيادة في السرعة) لمتزلج على الجليد على ارتفاعات مختلفة من أسفل التل.



عجلة المتزحلق على ارتفاع 350 متر تساوي _____

a. 6.2 m/s^2 b. 7.0 m/s^2 c. 7.4 m/s^2 d. 4.2 m/s^2

السؤال 3 : رياضية شابة كتلة جسدها 42 كجم ،في يوم لا رياح فيه، تجري العداءة 100 متر في زمن قدره 14.2 ثانية. الرسم البياني التالي (للتوضيح –ليس للقياس)يبين سرعتها أثناء السباق .

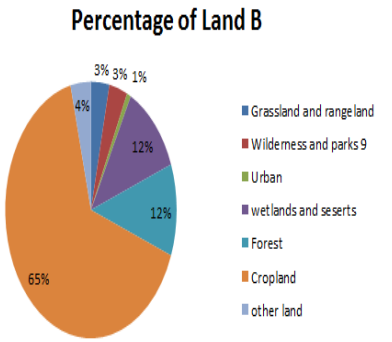


العجلة خلال الثلاث ثواني الأولى من جري العداءة تساوي :

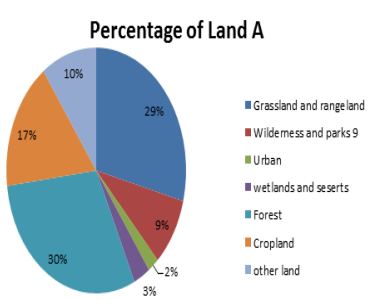
a. **0.37** m/s^2 b. **0** m/s^2 c. **24** m/s^2 d. **2.7** m/s^2

السؤال 4 :أي رسم من الرسومات البيانية الدائرية التالية يمثل البيانات المدرجة في الجدول عن نسب الأراضي تبعا لنوع استخدامها وطبيعتها؟

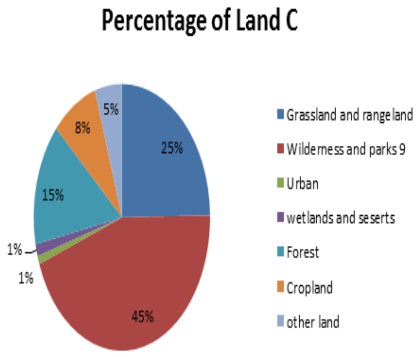
Kind of Land Use **نوع استخدام الأرض**	**Percentage of Land**
Grassland and rangeland الأراضي العشبية و المراعي	29
Wilderness and parks الأراضي البرية والحدائق العامة	9
Urban الحضر	2
wetlands الأهوار	3
Forest الغابات	30
Cropland الأراضي الزراعية	17
other land الأراضي الأخرى	10



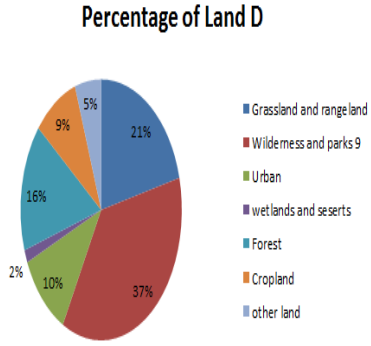
A.



B.

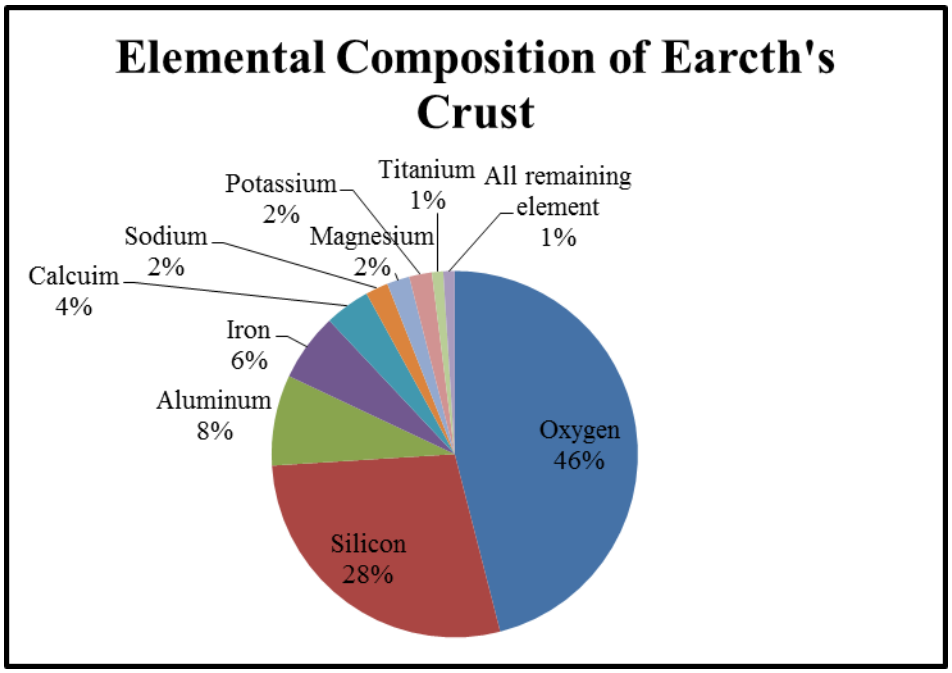


C.



D.

السؤال 5:الرسم البياني الدائري يبين العناصر المكونة للقشرة الأرضية حسب نسبها



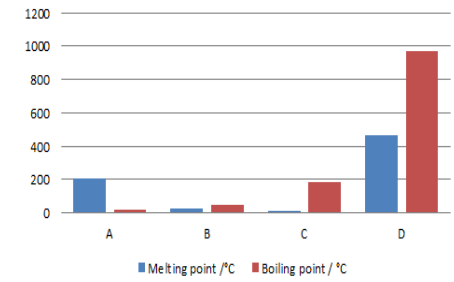
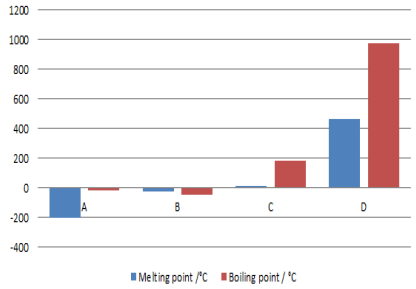
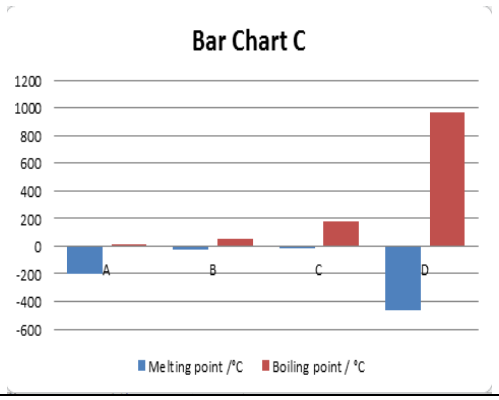
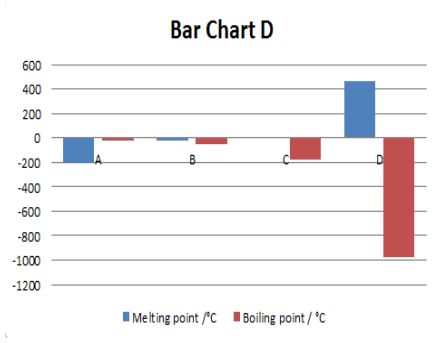
- ما هي نسبة عنصر المغنيسيوم (**Magnesium**) في القشرة الأرضية؟

A. 46% **B. 28%** **C. 1%** **D. 2%**

السؤال 6: الجدول التالي يبين درجات الانصهار و درجات الغليان لأربعة مواد

Substance المادة	Melting point /°C درجة الانصهار	Boiling point / °C درجة الغليان
A	-203	-17
B	-25	-50
C	11	181
D	463	972

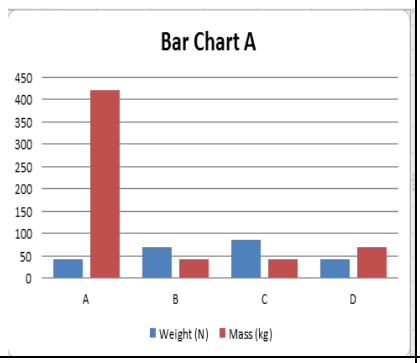
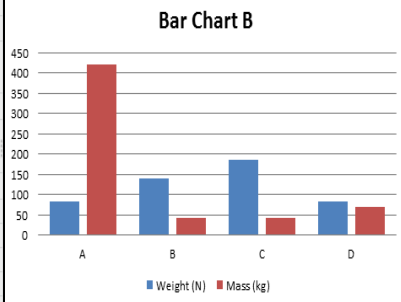
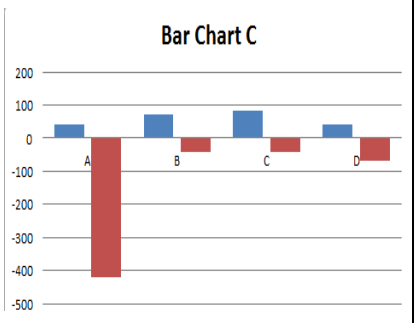
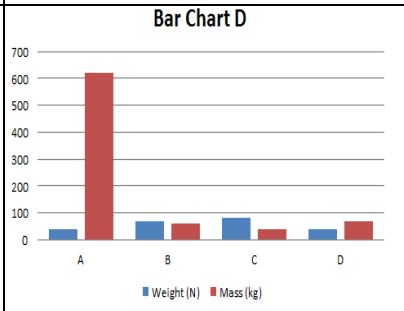
- حدد الرسم البياني الشريطي (Bar Chart) الذي يمثل البيانات المعطاة في الجدول أعلاه؟

<table>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>A.</td><td>B.</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>C.</td><td>D.</td></tr>
</table>

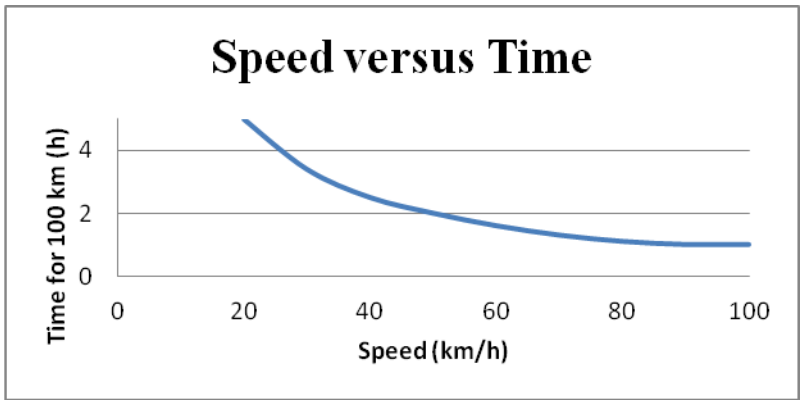
السؤال 7:الجدول يبين الوزن والكتلة لأربعة أجسام على سطح الأرض،ما هي كتلة ووزن هذه الأجسام على سطح القمر علما بأن الجاذبية على سطح القمر تساوي سدس الجاذبية على سطح الأرض؟

Objects	Weight (N)	Mass (kg)
A	42	420
B	70	42
C	84	42
D	42	70

- **حدد أي رسم من الرسومات البيانية الشريطية (Bar graph) التالية يمثل الوزن و الكتلة للأجسام الأربعة على سطح القمر؟**

<table>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>A.</td><td>B.</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td>C.</td><td>D.</td></tr>
</table>

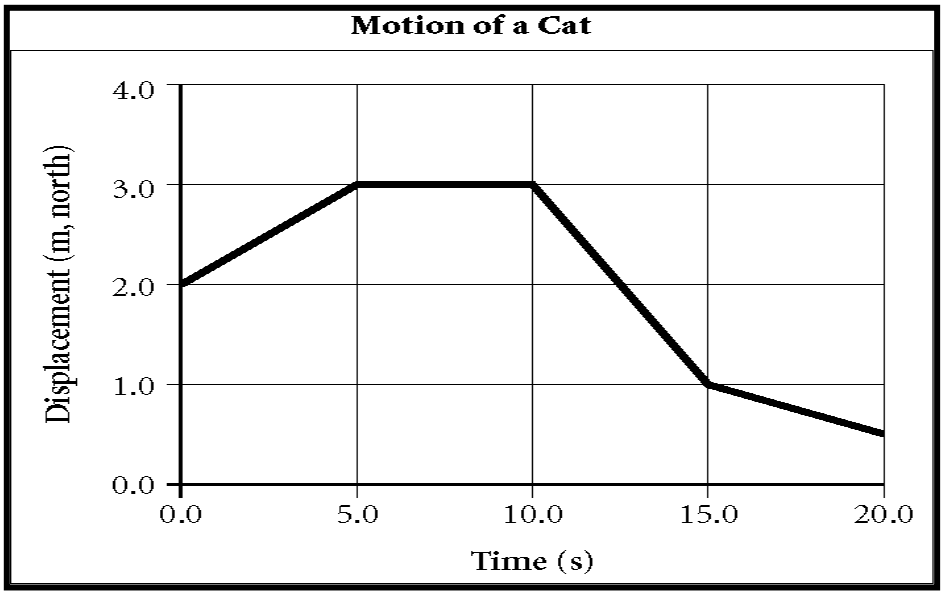
السؤال8:الرسم الباني التالي يمثل الزمن المطلوب لقطع مسافة 100 كيلو متر بسرعات مختلفة



- **ما هي السرعة المطلوبة لقطع المسافة المذكورة خلال ساعتين؟**

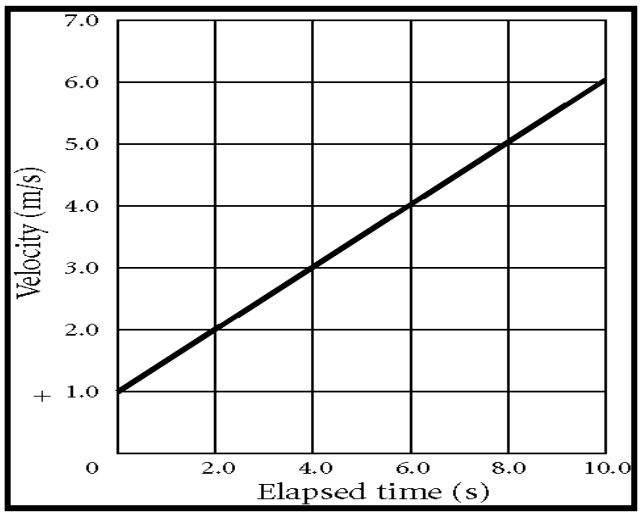
A. 20.0 km/h **B.** 40.0 km/h **C.** 50.0 km/h **D.** 90.0 km/h

السؤال 9:وفقا للرسم البياني الاتي في أي فترة زمنية تكون القطة ساكنة ؟



A. 0.0–5.0 s **B.** 5.0–10.0 s **C.** 10.0–15.0 s **D.** 15.0–20.0 s

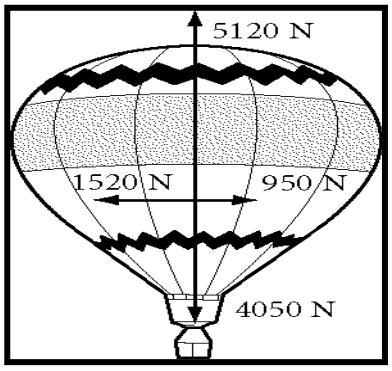
السؤال10: الرسم البياني التالي يمثل حركة سائق دراجة



- **العجلة بالنسبة لحركة سائق الدراجة**

A. constant **B.** Decreasing **C.** Increasing **D.** zero

السؤال 11: الرسم البياني التالي لجسم حر :

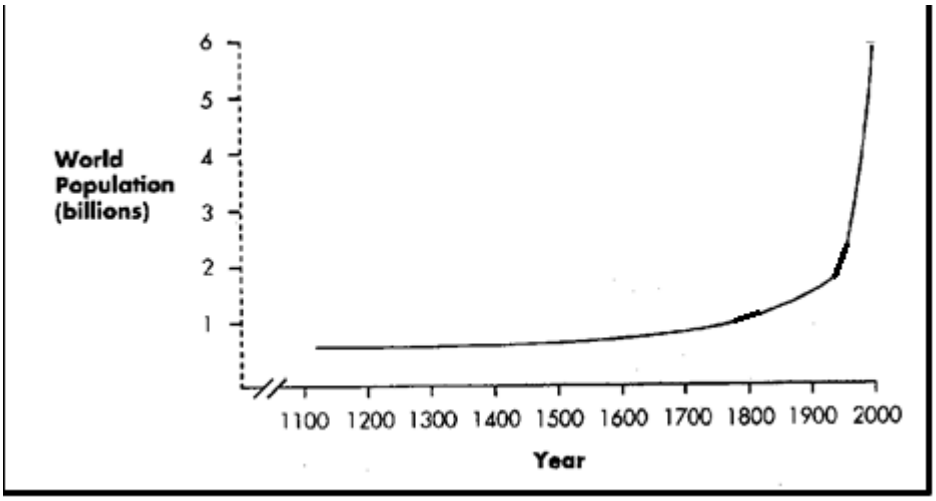


- **أي من التالي هي قوة الجاذبية المؤثرة على الجسم ؟**

A. 1520 N B. 950 N C. 4050 N D. 5120 N

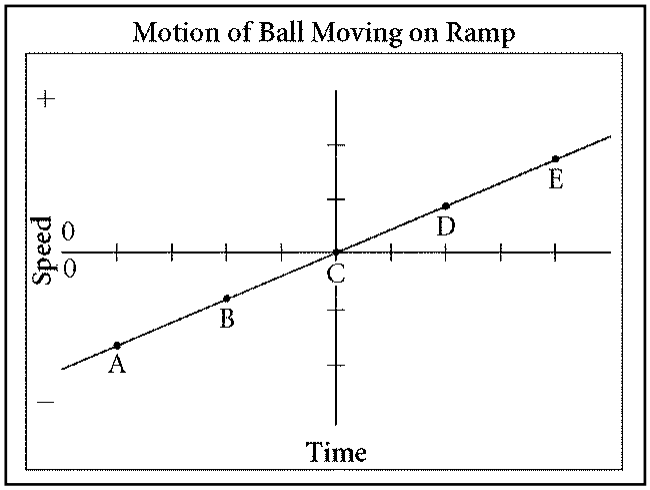
السؤال 12:الرسم الباني التالي يمثل عدد سكان العالم (بالمليارات billions) بمرور الزمن،كم عدد سكان العلم خلال القرن السابع عشر (1800) ؟

World Population Growth



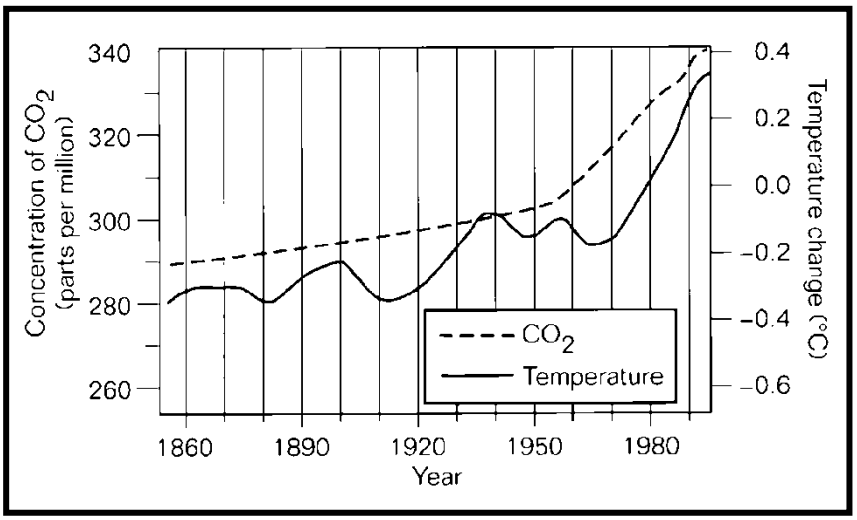
A. 500 ألاف **B.** مليون1 **C.** مليار 1 **D.** مليار 2

السؤال13:الرسم الباني التالي يصف حركة كرة.في أي نقطة تكون سرعة الكرة اللحظية صفر؟



A. A B. B C. C D. D

السؤال 14, 15 مرتبطان بالرسم البياني التالي



السؤال 14:الخلاصة المستنتجة من الرسم البياني هي

A. تركيز غاز CO2في الغلاف الجوي في الفترة من عام 1860 إلى عام 1995

B. التغيير في متوسط درجات الحرارة العالمية منذ عام 1995.

C. تركيز غاز الأكسجين في الغلاف الجوي في ازدياد منذ عام 1860.

D. ارتفاع درجات حرارة الكرة الأرضية مرتبط بظاهرة الاحتباس الحراري.

السؤال 15:ارجع للرسم التوضيحي أعلاه. وفقا للرسم البياني:

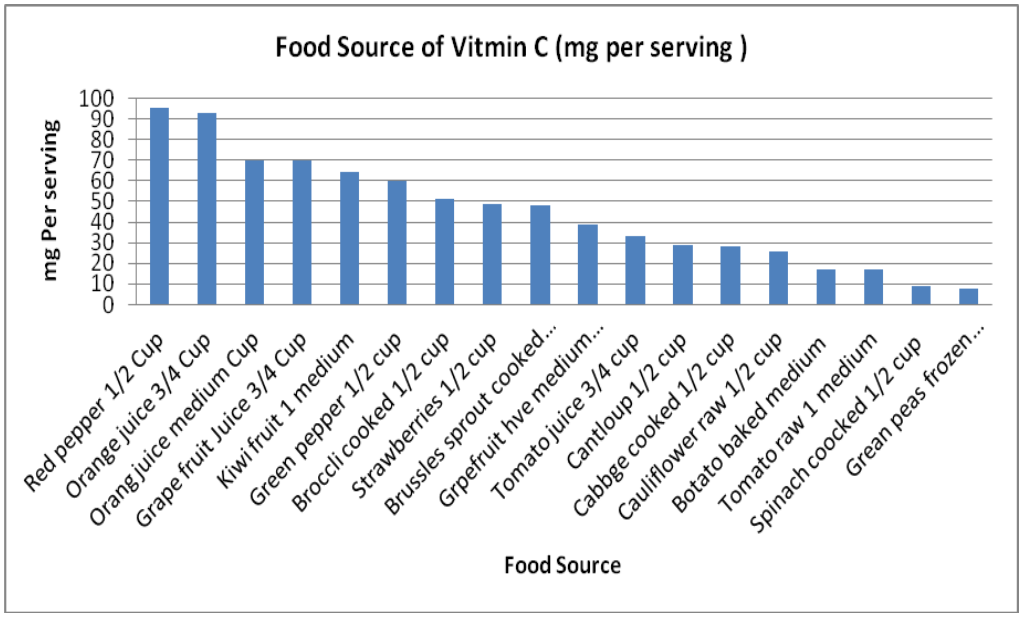
A. متوسط درجات الحرارة في العلم كان في زيادة مستمرة في الفترة من عام 1900 إلى عام 1950.

B. شهد تركيز غاز ثاني أوكسيد الكربون CO2 معدل نسبة زيادة ثابتة في الفترة من 1920 إلى 1980.

C. تركيز غاز CO2و الحرارة كانا متشابهين في عام 1990

D. غاز CO2و درجات الحرارة في تزايد منذ عام 1980.

سؤال 16 و 17 متعلقان بالرسم البياني التالي:



سؤال 16:ما هو أعلى معدل لفايتمينC (Vitamin C)

A. 89 B. 50 C. 93 D. 90

سؤال 17:ماهو مصدر الغذاء الذي يحتوي على أدنى مستوى لفايتمينC (Vitamin C)

A. Red pepper ½

B. Spinach cooked ½ cup

C. Tomato Raw 1 medium cup

D. Green Peas frozen