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THE EFFECT OF INCORPORATING THE CONTRIBUTIONS OF ARAB SCIENTISTS INTO A UNIT ON OPTICS ON MALE GRADE 10 LEBANESE STUDENTS' ATTITUDES TOWARDS SCIENCE: A COMPARATIVE CASE STUDY

by
FATIMA SAEED EL-ALI

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AN ABSTRACT OF THE THESIS OF

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Title: The Effect of Incorporating the Contributions of Arab Scientists into a Unit on Optics on Male Grade 10 Lebanese Students' Attitudes towards Science: A Comparative Case Study

It is important to promote scientific literacy among students, since they are the future citizens of a society that relies on the rapidly growing advances of science and technology. That is why one of the aims of science education reform worldwide is to increase students' interest in science courses and careers. Research around the world has found that attitudes are correlated with educational and career choices. Several factors have been found to influence students' attitudes towards science. These include gender and environmental factors which comprise structural variables, classroom/teacher factors, curriculum variables, perceived difficulty of science, and increasing range of subject choice. In investigating curriculum variables, researchers have found that culturally inclusive curricula that feature the contributions of culturally relevant scientists improve students' attitudes. Very little is known about the attitudes of Lebanese students towards the school science curriculum. This study incorporates the contributions of Ibn Sahl, an Arab scientist, into a unit on optics and examines its effect on students' attitudes. The participants were male tenth grade Lebanese students randomly assigned to two groups: experimental and control groups. The experimental group's teaching model incorporates the historical contributions of Arab scientists. The historical part is omitted from the control group's teaching model. Focus groups before and after the intervention were used to investigate students' attitudes towards this unit. The results indicate that that participants' attitudes towards science in the experimental group were positively affected by the incorporation of a cultural role model. The implications of the study's findings suggest the need for Lebanese curricular reform by shedding light on the importance of culturally inclusive curricula and its effect on students' attitudes.

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CHAPTER I

INTRODUCTION

Modern society relies tremendously on the rapidly growing advances of science and technology. This requires future citizens to have adequate expertise in the scientific and technological fields. It also increases the demand for a skilled workforce in these domains. Research around the world has found that attitudes are correlated with educational and career choices. That is why one of the aims of science education reform worldwide is to increase students' interest in science courses and careers (Millar & Osborne, 1998; Osborne, Simon, & Collins, 2003). A number of factors have been found to influence students' attitudes towards science. These include gender and environmental factors which comprise structural variables, classroom/teacher factors, curriculum variables, perceived difficulty of science, and increasing range of subject choice (Osborne et al., 2003; Simon & Osborne, 2010). According to Osborne and his colleagues (Osborne, Simon, & Collins, 2003), the influential curriculum variables cannot be precisely determined through studies solely concerned with comparing the influence of new and traditional curriculum materials on students' attitudes based on the collected data without deeply analyzing the differences between the curricula. Some studies, particularly qualitative ones, have been aiming on thoroughly inspecting these variables (Ebenezer & Zoller, 1993). Some researchers have found that culturally inclusive curricula that feature the contributions of indigenous scientists improve indigenous students' attitudes towards science (Key, 2003; McKinley, 2007; Ninnes, 2003).

Purpose and Statement of the Problem

This study sought to gain insight into the phenomenon of culturally inclusive science curricula as perceived by Lebanese students. The purpose of this study was to learn whether and how the incorporation of Arab scientists' contributions into a unit on optics influences Lebanese students' attitudes towards science. The current Lebanese science curriculum rarely mentions the work of Arab scientists or their impact on modern science. Reference to their work in the science curriculum may portray a positive cultural role model and an inspiring cultural representation for Lebanese students.

Research Questions

In this study, the following research questions were investigated:

1. Does incorporating the contributions of Arab scientists into a unit on optics improve Lebanese students' attitudes towards science and in what way?
2. How do Lebanese students perceive a culturally relevant science unit that incorporates reference to the contributions of Arab scientists?

Rationale

With the continuous advances in science and technology, the demand in societies for specialized citizens in these fields has increased. In societies seeking to keep up with science and technological advances, these citizens have a great influence on the community's current or future development. They will fuel the society's progress both as science practitioners and scientifically literate citizens. Students' attitudes have been linked with their educational and career choices (Koballa, 1988; Lin, 1998; Simon & Osborne, 2010). For this reason, science educators have been concerned with enhancing students' attitudes towards science (Osborne et al., 2003; Osborne & Collins, 2001; Simon & Osborne, 2010). Curriculum content is one of the variables that affect students' attitudes towards science (Osborne et al., 2003; Osborne & Collins, 2001; Simon & Osborne, 2010). Some educators advocate the inclusion of aspects of students' cultural background in science curricula to improve their attitudes towards science (Key, 2003; Lee & Luykx, 2014; McKinley, 2007; McKinley & Gan, 2014). This can be achieved by incorporating and highlighting the contributions of scientists from students' own cultural background to modern science in their science curricula (Key, 2003; McKinley, 2007; Ninnes, 2003).

Students' Attitudes towards Science

The decrease of young people's interest in studying science in developed countries has triggered educators to research attitudes. Studies have revealed that attitudes towards science consist of a large number of subconstructs all of which contribute, in varying proportions, to an individual's overall attitudes to science (Osborne et al., 2003; Simon & Osborne, 2010). Various studies, both quantitative and qualitative, have tried to depict some of those subconstructs such as: the perception of the science teacher, anxiety toward science, the value of science, self-esteem in science classes, motivation towards science, enjoyment of science, attitudes of peers and friends towards science, and attitudes of parents towards science (Simon & Osborne, 2010). Moreover, researchers have examined the various factors that may affect students' attitudes towards science and have specified the following: gender, environmental factors including structural variables, classroom/teacher factors, curriculum variables, perceived difficulty of science, and increasing range of subject choice (Osborne et al., 2003; Simon & Osborne, 2010). Despite the large number of studies conducted to improve students' attitudes using new curricular materials or instructional strategies, very few generalizations about specific effective curriculum features can be made (Simone & Osborne, 2010). This is because most of these studies do not provide clear analysis about how the new curriculum materials or teaching strategies differ from traditional ones (Krogh & Thomsen, 2005; Osborne et al., 2003). They are usually focused on solely comparing the influence of new and traditional curriculum materials on students' attitudes based on the studies' collected data. For this reason, this study made a careful contrast between the effect of incorporating HOS (History of Science) into science curricula and more specifically the effect of culturally relevant lessons that include reference to an Arab scientist in particular in a unit on optics on Lebanese students' attitudes towards science.

Moreover, qualitative studies yield more in depth insights into students' perceptions and views about the various features of science curriculum as compared to quantitative ones (Osborne & Collins, 2001). That is why most researchers suggest the use of qualitative methodologies in any study seeking to gain insight into the views and beliefs of students about what is regarded as an effective curriculum variable (Krogh & Thomsen, 2005). Therefore, this study used a focused group discussion with a group of Lebanese students to carefully investigate the impact of including Arab scientists' contributions in a physics unit on students' attitudes towards science.

History of Science

Several scholars argue that the history of science needs to be included in the science curriculum. It has been demonstrated that history of science provides meaningful perspectives about scientific concepts, processes, and context. Some curricula have adopted this view, such as the National Curriculum for England and Wales. It is stated in its publication that (Solomon et al., 1992):

Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed. (p.68)

This has stimulated further researchers to identify the effectiveness of integrating historical readings into science education. Studies show that teaching history of science does not only enhance students' conceptual, procedural, and contextual understanding. It also improves their attitudes towards science (Kotob, 2007; Lin, 1998).

In a Chinese context, Lin (1998) conducted a quasi-experimental study to investigate the effect of teaching freshman chemistry using historically rich supplemental material on students' attitudes toward science. All participants were taught using the same textbook while three supplemental historical cases were only introduced and explained to the experimental group. Both types of collected data, quantitative and qualitative, revealed the effectiveness of the HOS cases in promoting students' attitudes towards science. As reported in this study, students' appreciation for science increased in accordance with their enjoyment of learning through the historical descriptions. Similarly, Kotob's (2007) experimental study examined the possible effect of incorporating HOS into a Lebanese science classroom on Lebanese student's attitudes towards science. Following the Monk and Osborne Model (Monk & Osborne, 1997) which encompasses six phases (presentation, elicitation, historical study, devising test, scientific view, and review and evaluation), two Chemistry units were taught to two groups of participants. The historical study phase was omitted from the model in teaching the control group. An increase in the attitudes of students assigned to the experimental group towards science was reported.

Culturally Inclusive Science Education

In the debate about equity and equality in science education, researchers interested in the education of indigenous students stress the importance of recognizing and incorporating indigenous knowledge and their scientists' contributions to modern science in the science curriculum (McKinley, 2007; McKinley & Gan, 2014).

McKinley (2007) a professor of indigenous education at the University of Melbourne, defines indigeneity as a heterogeneous complex concept that includes First Nations and Third World contexts. In many Third World countries, European settlers did not attain majority by numbers and many of them did not stay. However, they have caused enormous influence on the countries' institutions and language (Maddock, 1981). Most of these communities are still subjugated by the historical and ongoing effects of their previous colonizers (McKinley, 2007). For instance, many of Third World contexts countries are still following the same formal education systems previously set by their Western colonial rulers. Those systems displayed the work of white Western scientists as valuable and worthy, while excluding and ignoring the contributions of indigenous scientists.

Other researchers point to the effect of the presence or lack of cultural images in the curricula on students (Key, 2003; McKinley, 2007). Indigenous students who had not encountered in their school years or read about a scientist from their own ethnic group may internalize the notion that they are incapable of doing science (Key, 2003). This might affect not only their personal image, but also their attitudes towards science and future educational and career choices (McKinley, 2007; McKinley & Gan, 2014).

This study focused on Lebanon, one of the Arab countries that have been subject to mandate rule by France. Its formal educational system is still mostly following the education system previously set by French mandatory powers. The contributions of Arab scientists are very rarely referred to in the Lebanese science curriculum.

Arising from the results of the previously reviewed research, this study investigated the influence of incorporating not any HOS materials in science curriculum, but culturally inclusive ones in particular, on students' attitudes towards science. This study investigated the effect of incorporating the contributions of Ibn Sahl, an Arab scientist, in a unit on optics on Lebanese students' attitudes towards science. Two grade ten sections were randomly assigned to two groups: an experimental and a control group. In the experimental group, the work of Ptolemy and Ibn Sahl (with a major focus on Ibn Sahl) were covered alongside Snell and Descartes' work. As for the control group, the lessons only covered the work of Snell and Descartes as illustrated in their National Lebanese physics textbook.

Significance of the Study

The study's significance lies in its attempt to explore and employ a model in teaching science through the work and contributions of previous scientists that will represent a cultural icon for students and enhance their involvement and motivation towards science. The study may impact both the theory of culturally inclusive science education in Lebanon and its implementation in schools.

On theory level, the findings of this study provide insights into Lebanese students' perception about the incorporation of Arab scientists' contributions in the science curriculum. The results of this study can be used to further elaborate on Lebanese students' opinions about the inclusion of Arab scientists in science curriculum. In addition, this study explored the effect of this inclusion on Lebanese students' attitudes towards science. This may set up a starting point for future studies to investigate its effect not only on students' attitudes but also their identities or other factors. Moreover, this study may also set a starting point for further research to be carried out on a larger scale in the Lebanese context. Generalizations from such studies might also trigger other Arab communities to broaden this research field in order to thoroughly understand the effects of including the work of Arab scientists in the science curricula of Arab countries. They might be interested in replicating these studies to explore their findings in their own communities.

On the practical level, this study can encourage curriculum developers in Lebanon and the Arab World to consider including the contributions of Arab scientists in science curricula and science textbooks. It might also motivate Lebanese science teachers to expand their knowledge about Arab scientists, present them in classrooms as cultural representations, and point out to their contributions in order to engage Lebanese students and inspire them to pursue further science education and science-related careers.

CHAPTER II

LITERATURE REVIEW

Introduction

The demand for specialized citizens in science and technological fields has increased in modern societies (Hodson, 2003). This increase is due to the continuous advances in science and technology worldwide. In democratic societies, specialized citizens in these fields will not only fuel the society's progress as science practitioners but also as scientifically literate citizens and decision makers. Science educators have been concerned with enhancing students' attitudes towards science (Osborne, Simon, & Collins, 2003; Osborne & Collins, 2001; Simon & Osborne, 2010). This is because students' attitudes have been linked with their educational and career choices (Koballa, 1988; Lin, 1998; Simon & Osborne, 2010). One of the factors that affect students' attitudes towards science is curriculum content (Osborne et al., 2003; Osborne & Collins, 2001; Simon & Osborne, 2010). Most science curricula around the world refer mainly to the contributions of Western male scientists to modern science (Key, 2003; McKinley, 2007; McKinley & Gan, 2014). This is found to affect the attitudes of students from other cultural groups and female students who often do not identify with these representations of scientists (McKinley, 2007; McKinley & Gan, 2014; Ninnes, 2003). That is why some educators advocate the inclusion of culturally related materials in science curricula to improve indigenous students' attitudes towards science (Key, 2003; Lee & Luykx, 2014; McKinley, 2007; McKinley & Gan, 2014). This can be achieved by incorporating the contributions of previous indigenous scientists to modern science in science curricula (Key, 2003; McKinley, 2007; Ninnes, 2003).

The aim of this chapter is to provide a comprehensive review of the literature concerning students' attitudes towards science, on the one hand, and the impact of both historically and culturally inclusive science curricula on their attitudes, on the other hand.

Attitudes towards Science

Science education reform worldwide is concerned with promoting students' interest in science courses and careers. As discussed by Osborne and his colleagues (Osborne et al., 2003), there are several reasons for this concern. The first cause for concern as revealed in the literature (Osborne et al., 2003; Simon & Osborne, 2010) is the persistent decline in the number of students choosing science courses with no notable change in the male to female ratio. The analysis by gender reveals that physics courses are still dominated by males, while the number of females is higher in biology courses (Simon & Osborne, 2010). The second cause for concern is the drop of the number of competent and expert scientists in societies caused by the decrease in the number of students pursuing science. This will negatively affect societies' economic futures since it relies on the proficiency of its citizens in science and technology. Accordingly, in order to make school science more interesting and engaging for students, there is a need to define attitudes towards science, identify their appropriate methods of measurements, and recognize the crucial influencing factors involved. Enhancing students' attitudes towards science will further promote their scientific literacy as future citizens and decision makers.

Defining "Attitudes towards Science"

Gardner (1975) distinguished between "attitudes towards science" and "scientific attitudes"; the latter are cognitive in nature and encompass aspects of scientific thinking, while attitudes *towards* science comprise mainly the feelings and values held *about* science, scientists, school science, and its impact on society. A more recent study by Kind and his colleagues (2007) claims that attitudes toward science can be measured based on the following seven constructs: learning science in school, practical work in science, science outside of school, importance of science, self-concept in science, future participation in science, and combined interest in science. This study investigates Lebanese students' attitudes towards science. When investigating attitudes towards science, educators and researchers are faced with two challenges: to understand the composition of attitudes towards science and their effects on behavior.

First, attitudes towards science consist of a large number of subconstructs all of which contribute, in varying proportions, to an individual's overall attitudes to science (Osborne et al., 2003). As listed by Simon and Osborne (2010), these subconstructs include: the perception of the science teacher, anxiety toward science, the value of science, self-esteem in science classes, motivation towards science, enjoyment of science, attitudes of peers, friends, and parents towards science, the nature of the classroom environment, achievement in science, and fear of failure of the course.

Second, a person's behaviors may not be necessarily related to his/her feelings and attitudes towards a certain object (Potter & Wetherell, 1987). In other words, students' attitudes towards the studied object may not be revealed in their behaviors. For example, as pointed out by Simon and Osborne (2010), students' behaviors may be inconsistent with their interest in science because it is not considered by their peers as a "cool thing". The influence of social context and personal interests on an individual's behavior varies among students (Crawley & Coe, 1990). Students value these two factors differently; some place greater influence on their interests, while others conform to the views of important persons in their lives, and others take both factors into consideration before acting.

Following Gardner’s definition of attitudes towards science (1975), this study focused on four main concepts that delineate students’ attitudes towards science. These concepts are the following: attitudes towards science, attitudes towards scientists, interest in pursuing further science education and career, and impact of science on society.

Quantitative Measurements of Attitudes towards Science

Researchers seeking to measure students’ attitudes towards science have used both quantitative and qualitative methodologies. However, this domain has been traditionally dominated by quantitative methods (Krogh & Thomsen, 2005). These include subject preference studies, attitude scales, interest inventories, and subject enrolment (Osborne et al., 2003).

Subject preference studies. Subject preference methodology is simple to use; students are asked to rank their liking of school subjects. Its results are easily presented and interpreted. Using this methodology, researchers have found that chemistry and physics are the least popular school subjects (Whitfield, 1980), with chemistry being less appealing than physics (Osborne & Collins, 2000). Critics have pointed out that this method is considered a relative scale and not suitable for measuring attitude changes (Kind, Jones, & Barmby, 2007), unless students are asked to rank science in comparison with other subjects (Osborne et al., 2003; Simon & Osborne, 2010). This reveals the inaccuracy of basing a study’s results on students’ subject preferences; a student may have positive attitudes towards all school subjects with science being the less popular, while the other student may have negative attitudes towards all subjects with science being the less disliked.

Attitude scales. Attitude scales are commonly used in researching students' attitudes towards science (Simon & Osborne, 2010). They are usually questionnaires that comprise Likert-scale items; students are asked to select from a four-point choice or more usually consisting of "strongly agree/agree/not sure/disagree/ strongly disagree" the best match to their response to several statements such as "science is fun", "I would enjoy being a scientist", and "science makes me feel like I am lost in a jumble of numbers and words" (Osborne et al., 2003). Critics highlight that attitudes encompass a large number of subconstructs with each having a role in shaping students' attitudes towards science. They represent attitudes towards science as a whole, but each one refers to a distinctive perception such as students' attitudes towards science in schools, students' attitudes towards science outside school, or students' attitudes towards scientists (Ramsden, 1988). Critics question the significance of interpreting an attitude scale that encompasses items of disparate subconstructs (Kind, Jones, & Barmby, 2007; Osborne et al., 2003). Gardner (1975) states that in order to obtain a meaningful score out of an attitude scale, items must be related to a single well-defined attitude subconstruct. The score yielded from an attitude scale covering several attitude subconstructs is meaningless; it resembles the measurement of the weight, length, and height of a dining table each having a meaningful index, but when added together they yield an uninterpretable variable (Gardner, 1975; Osborne et al., 2003). Hence, when composing an attitude scale a clear description of the subconstructs should be provided coupled with justification when disparate subconstructs are combined to form one scale (Kind, Jones, & Barmby, 2007).

Interest inventories. Interest inventories aim to determine students' science interests. Students are normally presented with a list of items and asked to indicate the ones they are interested in. This methodology is usually restricted to a specific focus and provides a limited view of possible students' attitudes towards science (Osborne et al. 2003).

Subject enrolment. Subject enrolment studies provide data on students' enrolments in school subjects or courses. For instance, TIMSS data for European countries reveal that gender differences in favor of males appear in the earth and physical sciences at the fourth grade level, with Netherlands having the largest overall gender gap at this grade (IEA, 2000). These gender differences widen at eighth grade to comprise also physics and chemistry and continue through to the final year of secondary school. The exclusive reliance on subject enrolment data while inspecting students' attitudes towards science is questionable (Osborne et al. 2003). This is because students' subject choices can be highly affected by several factors regardless of their personal interest in science. These may include society's economic structure, perception of friends and parents, perceived difficulty of the subjects, and gender stereotypes.

Qualitative Measurements of Attitudes towards Science

As reviewed above, general quantitative measures provide a limited understanding of students' attitudes towards science. Hence, there is a need to examine attitudes using qualitative methodologies in order to thoroughly inspect students' attitudes towards science (Krogh & Thomsen, 2005; Osborne et al., 2003; Simon & Osborne, 2010). Individual interviews are one of the qualitative methods that provide researchers with insightful data about students' experiences, views and beliefs. However, this method is extremely time-consuming (Osborne & Collins, 2001);

researchers need a lot of time to collect a representative sample of views and opinions. As an alternative, researchers use focus group discussions (FGD). This is a time efficient methodology. It consists of a dynamic group interaction where participants freely express and discuss their views and positions in a non-threatening environment with the supervision of a moderator. Unlike in individual interviews, participants in FGDs are not compelled to answer any question or feel pressured to make up a story just to please the interviewer. This increases the accuracy of the collected data about participants' views.

In their study, Osborne and Collins (2001) used FGDs to thoroughly inspect students' views of the role and value of the science curriculum. Rich data was collected about students' perspectives and their reactions to their school science experiences. For example, students expressed the importance of science mainly emphasizing its instrumental value. They made little reference to its aid in engaging critically with contemporary scientific dilemmas or its value as a cultural resource. Besides, students revealed the uninteresting aspects of school science which included difficult subjects, rushed curriculum, repetition and lack of discussion. They also acknowledged the interesting aspects such as practical work (experimentation and investigation) and challenging topics.

Factors influencing Attitudes towards Science

Students develop their scientific literacy through formal education in schools along with non-formal education outside school. Attitudes are one aspect of a student's science literacy in conjunction with science-related capabilities, values, approaches and knowledge (Kaya, 2012). As such, students' attitudes towards science are influenced by both out-of-school and in-school factors (Anwar & Bhutta, 2014; Fung, 2002; Kaya, 2012, Osborne et al., 2003). A brief overview of the literature concerning some of the main factors influencing students' attitudes will be provided in this section. These comprise the following: gender, family and cultural background, and school variables including quality of teaching and curriculum materials.

Gender. Gender is an important factor affecting students' attitudes towards science (Simon & Osborne, 2010; Tytler, 2014). A study conducted by Smith and his colleagues (Smith, Pasero, & McKenna, 2014) examined the relationship between gender and attitudes towards science in fourth and eighth grade US students. The results revealed that boys in both grades showed more confidence in science than girls. Additionally, eighth grade boys demonstrated greater liking for science than girls. Another study carried out by Murphy and Whitelegg (2006) revealed that the disparity between male and female students' attitudes towards science is manifested more in physics than in biology courses; the participation in physical sciences and engineering is persistently dominated by males (OECD, 2006). In the United States, the overall number of females in university faculties is the highest in health sciences, followed by biological science, with the fewest in engineering faculties (Scantlebury & Baker, 2014). Studies have suggested that this disparity might be explained by differences in boys' and girls' perspectives and interests in science topics (Blickenstaff, 2005; Haussler & Hoffmann, 2002). Boys seem to be more interested in topics discussing explosive chemicals, the atom bomb, and biological weapons (Blickenstaff, 2005). Girls seem to be more interested in a physics curriculum that encompasses more human-related content (Krogh & Thomsen, 2005). Taking into consideration their different perception of science, researchers have questioned the suitability of using the same curricula for both genders (Haste, Muldoon, Hogan, & Brosnan, 2008; Tytler, 2014).

Family and cultural background. Family's role in influencing students' attitudes towards science mainly comprises the following aspects: encouraging early interest, support for scientific reasoning, supporting positive self-efficacy, and providing role models and advice (Tytler, 2014). For example, parents' interactions with their children in museum exhibits nurture their scientific literacy, develop their scientific thinking, and increase their interest in science (Crowley, Callanan, Tenenbaum, & Allen, 2001). However, this interaction may differ with sons and daughters based on parents' cultural beliefs and views about science (Tenenbaum & Campbell, 2003). Parents tend to use more intellectually challenging science speech with boys than girls believing that science is uninteresting and difficult for daughters. Moreover, students whose parents are university-educated are more likely to enroll in science subjects (Adamuti-Trache & Andres, 2008). Such parents tend to engage their children more in science activities and have high expectations and belief in their children's capabilities and academic achievements.

School variables. School variables are also found to have strong influences on students' attitudes towards science (Simpson & Oliver, 1990). They encompass classroom environment, classmates' attitudes, quality of teaching, and curriculum variables. The last two variables are of particular interest in this study.

Quality of teaching. As discussed by Lyons (2006), students complain that school science is irrelevant to their daily lives and interests; they object to the overemphasis of copying notes from the classroom's board or other resources, and the repetitiveness and superficiality of science curriculum. Direct traditional teaching strategies such as lecturing fail to stimulate students' interest and engagement in science subjects (Weimer, 2002). Hence, researchers advocate the use of active-learning pedagogies which emphasize the involvement and engagement of students in their science knowledge construction through a cycle of thinking and investigative activities (Allen & Tanner, 2005; Connell, Donovan, & Chambers 2016). This provides students with the opportunity to explore their world and find out about the wonders of nature through investigative science activities. Several studies have revealed that active-learning instructional strategies enhance students' attitudes towards science (Preszler, Dawe, Shuster, & Shuster, 2007; Prince, 2004). For instance, following the use of wireless student response systems in six biology courses at New Mexico State University, the majority of students showed interest in technology and believed that it improved their understanding and interest in the course (Preszler et al., 2007).

Curriculum Variables. Various studies have examined possible strategies and ways to introduce science in an engaging and appealing way to students. Two of these strategies are of relevance to this study: the incorporation of history of science in science education and the integration of culturally relevant materials into science curricula. In his experimental study, Kotob (2006) supported the use of a historical perspective in science curriculum as a way to change students' views about the elements of the nature of science and their attitudes towards science. His study involved two groups, a control and an experimental group. The experimental group was taught a chemistry unit using the Monk and Osborne Model (Monk & Osborne, 1997) using a historical perspective, whereas the control group was taught the same unit following the same model but without the historical components. A comparison of the results using ANCOVA revealed a significant gain in the means of the attitudes scores and those of the nature of science scores. Key (2003) demonstrated that African American students are more interested in studying culturally relevant science topics than those that do not relate to their culture. Using an interest survey, students' perceived interests concerning culturally inclusive science topics in a traditional science curriculum and STS (Science-Technology- Society) curriculum were measured. The results revealed that students are interested in studying science topics that relate to their culture no matter whether the curriculum was traditional or STS. Thorough analyses of the effectiveness of these two strategies will be provided in the following sections.

The Effectiveness of Incorporating History of Science in Science Education

Science educators have proposed and developed various strategies to introduce science in an engaging and appealing way to students. One of the advocated strategies is the incorporation of history of science (HOS) into science curricula. It is demonstrated in the literature that history of science provides meaningful perspectives about scientific concepts, processes, and context. Some curricula have adopted this view, such as the National Curriculum for England and Wales. It is stated in its publication that (Solomon et al., 1992):

> Pupils should develop their knowledge and understanding of the ways in which scientific ideas change through time and how the nature of these ideas and the uses to which they are put are affected by the social, moral, spiritual and cultural contexts in which they are developed. (p.68)

Studies also reveal that the integration of historical readings into science curricula humanizes science education, enhances students' conceptual, procedural, and contextual understandings of science, and further increases their interest in science (Matthews, 1992; McComas et al., 1998; Solomon et al., 1992, Wang & Marsh, 2002).

The Humanization of Science Education

The traditional science curriculum lacks any relevance for the everyday world (Osborne & Collins, 2000) and conveys stereotypical images about science and scientists (Milne & Taylor, 1998). That is why there have been attempts to humanize science education by portraying science as a human endeavor. History of science humanizes science education by associating the individual's experiences with the scientific figures, highlighting and valuing the interplay of science and society, and providing cultural awareness (Wang & Marsh, 2002).

The Copernican revolution is an example of historical case that can be used to portray science as a human endeavor. Back in the fourth Century BC, Aristotle stated that the Earth is the center of a finite universe, and that the Sun, planets and stars orbit around it (Chalmers, 1999). However, in the sixteenth century Copernicus suggested that the earth is not stationary at the center of the universe but orbits the sun along with the planets, which is opposed to Aristotle's theory. He was faced with counter arguments and was not able to convince his critics during his lifetime. The most problematic one was the tower argument. This stated that if the earth spins on its axis then any point on the Earth's surface will move a considerable distance in a second. Thus, if a stone is dropped from the top of the tower erected on the moving earth, it will strike the ground some distance from the foot of the tower. But in actual fact, the stone strikes the ground at the base of the tower. Copernicus's view was rejected by most scientists, until Galileo in 1609, a century after him, defended the Copernican system by collecting relevant evidence using a telescope and devising the beginnings of a new mechanics. His observational data, through the telescope, were straightforwardly accommodated into the Copernican system. Besides, Galileo's new mechanics provided the Copernican system with some justifications. For instance, in response to the tower argument, the object held at the top of the tower shares with it a circular motion around the Earth's center, will continue along with the tower in that motion after it is dropped. Therefore, the object will strike the ground at the foot of the tower, which is consistent with experience. Moreover, Kepler's laws that planets move in elliptical orbits around the Sun, and that a line joining a planet to the sun covers equal areas in equal times, contributed to the strengthening of the Copernican theory. Later on, Newton's laws of motion provided the theory with further developments and enabled it to become securely based on a comprehensive physics.

Upon reading about Copernicus's struggle and the rejection of his ideas by the scientists during his time, students will perceive scientists as hardworking individuals who faced difficulties during their attempt to contribute to the scientific progress and relate them to their personal experiences. Moreover, the Copernican revolution example portrays the connectedness between science and society; the acceptance of scientific ideas is influenced by the views and beliefs of the society. It can also be used to exemplify how different cultural perspectives affect and shape scientific research; older scientists were not actually wrong, but had different equipment than nowadays, and looked at the world from a different perspective.

The Enhancement of Students' Conceptual, Procedural, and Contextual Understandings

Wang and Marsh (2002) discuss how history of science enhances students' conceptual, procedural, and contextual understandings. First, history of science has been shown to improve students' conceptual understanding by enriching the presentation of scientific knowledge and emphasizing its tentative nature. For instance, using again the

Copernicus example, after analyzing a historical reading about his revolution, students will be acquainted with how scientists work. The types of arguments used by Galileo to support his view can be highlighted by the teacher. As discussed by Nersessian (1989), Galileo began to put forth the position of his opponents, and then he exposed the difficulties in such a position. Galileo created a conflict; he used idealization techniques and analogical arguments to get others to construct his representation. Thus, students can become aware of the process of argumentation scientists undergo when sharing their views with the science community, and the ways through which new conceptual schemes replace older ones.

Second, history of science enhances students' procedural understanding by expanding within students the process of thinking, the process of investigation, and the processes of concluding, inferring, elaboration, reporting, and application (Marsh & Wang, 2002). For example, introducing the development of a theory helps students' conceptual change. By reflecting on the process of concept development made by the scientists, students will recognize and modify their own misunderstandings within their conceptual framework. Thus, substantial learning will take place. Third, history of science improves students' contextual understanding by identifying the psychological factors that are involved in the following: science making, process of interaction between scientists and society, and cultural factors associated to the science research (Marsh & Wang, 2002). For example, historical readings include the factors that motivated or inspired the scientists to do research.

The Enhancement of Students' Attitudes towards Science

Few research studies have been concerned with investigating the possible positive effect of using the historical approach on students' attitudes towards science

(Lin, 1998; Kotob, 2006). Matthews (1994) states that history “makes science and engineering programs more attractive to many students” (p.7); he further adds that it “humanizes the subject matter of science, making it less abstract and more engaging for students” (p. 50). This implies that HOS might promote students’ attitudes towards science.

Lin (1998) investigated, in a quasi-experimental study, the effect of teaching freshman chemistry using historically rich supplemental material on Chinese freshmen students’ attitudes toward science. Two classes comprising sixty-one students participated in this study. In one school year, all students used the same textbook. However, as a treatment in this study, three supplemental historical cases of chemistry were taught only to the experimental group. The cases covered how Boyle used a J tube to confirm the compressibility of air and the pressure of air in the seventeenth century, how the phlogiston theory was overthrown and the existence of oxygen was proven, and how the atomic theory, the atomic weight table, the formula of water, and Avogadro’s molecular hypothesis were developed. Students in the experimental group were expected to develop a better understanding of the covered topics providing them the opportunity to be acquainted with how scientific theories get accepted, how earlier scientists held alternative conceptions, and how creativity is essential to the nature of science. Both types of collected data, quantitative and qualitative, revealed that the three cases of history significantly promoted the students’ attitudes toward science. The qualitative data reported from the interviews provided stronger evidence of the effectiveness of teaching chemistry through historical cases; students’ appreciation for science increased in accordance with their enjoyment of learning through the historical descriptions.

In his experimental study, Kotob (2006) examined the possible effect of the incorporation of history of science into a Lebanese science classroom on Lebanese students' attitudes towards science. The sample consisted of 48 grade eight students in a private school of low socioeconomic status. Two sections, to which students were randomly selected at the beginning of the school year, participated in the study; one as the experimental group and the other as the control group. Students were taught two chemistry units (atomic theory and chemical reactions) using the Monk and Osborne Model (Monk & Osborne, 1997). This model encompasses six phases: presentation phase, elicitation phase, historical study phase, devising test phase, scientific view phase, and review and evaluation phase. As an intervention, students in the experimental group were taught the two units using the six phases, while the historical study phase was omitted from the model in teaching the control group. In the historical study phase, teachers were required to research and present to students early thinking about the phenomenon, background information on the economic/social/political situations of the time, an example of opposing ideas from other scientists and their supporting arguments, and a brief chronology of the related dates and events. The quantitative results of the pre- and post-tests revealed an increase in the positive attitudes to science of students assigned to the experimental group.

The results of the two previous studies demonstrate the effectiveness of incorporating history of science in science curriculum in improving students' attitudes towards science. This raises a further question: "which contributions of previous scientists should be referred to and considered effective in in influencing students' attitudes to science?" As previously mentioned, most science curricula around the world refer mainly to the contributions of Western male scientists to modern science (Key, 2003; McKinley, 2007) which can affect the attitudes of students from other cultural groups who often do not identify with these representations (McKinley & Gan, 2014; Ninnes, 2003). That is why some educators advocate the inclusion of the contributions of previous indigenous scientists to modern science in science curricula (Key, 2003; McKinley, 2007; Ninnes, 2003). These will serve as cultural representations that will enhance the attitudes of indigenous students towards science and increase their engagement in both educational and career science fields. A review of some main issues concerning culturally inclusive science curriculum will be provided in the following section.

Culturally Inclusive Science Curriculum

Researchers have long been debating the nature of knowledge in the field of culture and science education (Mckinley, 2007; Stanley & Brickhouse, 2001). While holders of the universalist position view science as a universal body of knowledge with Western modern science (WMS) being the paradigmatic and most powerful example of science, the pluralists understand scientific knowledge as a product of its culture and argue that portraying WMS as universal devalues and undermines indigenous sciences (McKinley, 2007). Moreover, educators have been interested in providing diverse student populations equal and equitable learning opportunities (McKinley, 2007; Ninnes, 2013). They call for equal recognition of diverse groups' languages, cultures, and resources. This includes the acknowledgment of Non-Western's contributions to the scientific knowledge, which complies with the pluralist approach. The following section will address issues of indigenous learners in postcolonial societies. They exemplify one of the underrepresented groups in science education that have often been subject to historical and ongoing effects of colonization (McKinley, 2007; Snively & Corsiglia, 2000).

The Underrepresentation of Indigenous Communities in Science Curricula

As defined by McKinley (2007), indigeneity is a "heterogeneous complex concept that is contextually bound" (p. 202). It encompasses societies that have been colonized and whose colonizers have become numerically dominant like First Nations or whose settlers never attained majority by number and eventually left like Third World contexts. It also includes societies that claim to be indigenous but are not necessarily recognized as such in their own countries or that have no land to call home. Science education in many indigenous communities is still influenced by their colonizing experience (McKinley, 2007; McKinley & Gan, 2014). Their language, culture, and resources are not acknowledged in their own science curricula.

Western European colonizers aimed to "modernize", "civilize", and "instruct" the colonized communities (McKinley, 2007). They caused enormous changes in educational institutions. First, settlers downgraded indigenous languages and considered them an obstacle in the civilization process (Marker, 2004). Accordingly, these languages were banned in schools and replaced by the colonizers' languages. Indigenous people came to believe that their languages were inferior and continued to use the colonizers' languages in their education system even after colonizing countries handed over power. For example, math and science subjects in Lebanon, an Arab country, are taught in public and private schools in English or French; French is the language of its previous colonizer. This undermines the Arabic language in the Lebanese community and promotes the idea that English and French are more important than the community's mother tongue. Languages are essential for maintaining worldviews, cultures, and knowledge (Aoki & Jacknice, 2005). Thus, in order for indigenous communities to preserve and sustain their history, culture, and knowledge, they need to preserve their mother tongue.

Moreover, colonizers transplanted familiar objects from their homeland to the colonized countries including books and curricula (McKinley, 2007). For instance, in Aotearoa New Zealand, settlers imported flora and fauna which caused significant damages to some native species such as flightless birds (Crosby, 2004). Until the early 1970s, the science curriculum taught to Maori students was mainly based on imported exotic plants planted by the settlers around schools (McKinley, 2007). Nowadays, the curriculum continues to focus on plants connected to previous settlers such as the pasture plant, planted by previous colonizers for the development of the lands as farms, because there is a significant amount of research about it unlike native plants.

Furthermore, the science curriculum established by colonizers highlights the contributions of Western Europeans to scientific knowledge and disregards the significant work of non-Western non-Europeans. Today, this neglect continues in many previously colonized communities' science curricula. For instance, the contributions of Ibn Al-Haytham and Ibn Sahl, two Arab scientists, are not cited in chapters covering optics in National Lebanese physics textbooks. Lebanese students are only informed in school science about the work of Western European scientists. As a result, school science may be seen as foreign to them due to the fact that they study science for years before reading about a scientist or inventor of their own ethnic group (Key, 2003). Consequently, students may internalize the idea that they cannot perform science; they do not relate nor connect with the scientists mentioned in their science curricula. This lack of cultural representation may influence students' attitudes, interests, and further educational and career choices in any science domain (McKinley, 2007).

This raises the following questions: "what should be included in an indigenous science curriculum?", "how important are the contributions of indigenous scientists to the science field?", "how should the contributions of indigenous scientists be incorporated into science curricula?", and "how can culturally inclusive science curriculum be implemented in classrooms?" An attempt to examine and discuss answers to these questions will be provided in the following section.

The Effectiveness of Culturally Inclusive Science Curricula

The NSF (1998) promotes the incorporation of "culturally and gender relevant curriculum materials" that recognize various "cultural perspectives and contributions so that through example and instruction, the contributions of all groups to science will be understood and valued" (p.29). Several studies have further investigated the effectiveness of culturally inclusive science curricula. These studies revealed that such curricula promote higher science achievement among indigenous students, enhance their attitudes towards science, and foster their cultural identity (Aikenhead, 1997; Matthews & Smith, 1994). Yet, the application and adoption of culturally inclusive science curricula in the practical field is faced with several challenges.

To begin with, materials designed to portray and highlight indigenous knowledges encounter several problems. Ninnes (2000) conducted a content analysis to examine the incorporation of indigenous knowledges in two sets of junior secondary science textbooks, one published in Australia and the other one in Canada. His analysis revealed that textbooks contained significant amounts of information about indigenous knowledges in the following domains: legends and myths, the natural world, technology, and social activities. However, these textbooks illustrated indigeneity as a homogenous category which might generate racist stereotypes. Moreover, representations of indigenous lifestyles were labeled as traditional subjugating therefore the identity of indigenous people. Ninnes (2000) argues that culturally inclusive science curricula should depict more perceptive and thoughtful representations of human diversity; it should objectively portray indigenous scientists' contributions without any label or categorization as primitive or traditional.

Eide and Heikkinen (1998) conducted a content analysis of teachers' editions of twenty one middle school science textbooks in the aim of determining how the incorporated multicultural content within these manuals helps in science teaching in multicultural classrooms. The study focused on the following: (a) the extent of multicultural content; (b) the distribution of multicultural content within foundational knowledge categories; and (c) the relationship to the science content. Their analysis revealed that multicultural content is not sufficiently portrayed or explained in teacher resource manuals. They state that teachers' manuals do not often include the reason for incorporating information about cultural diversity. In addition to that, these manuals rarely provide suggestions on how teachers can make use of the multicultural information to support the associated learning objectives. Eide and Heikkinen (1998) conclude that science textbooks have to complement the learning outcomes of multicultural content that should be explicitly depicted. Moreover, they emphasize on the importance of the role of teachers in amplifying and elaborating on not only the awareness and understanding of multicultural content but also its interconnectedness with the diversity in various societies.

Taking into consideration the effects of cultural integration in science curricula on indigenous students, some researchers sought to overcome the previously mentioned challenges. In an attempt to explore and produce some teaching strategies and materials for multicultural science education in classrooms, Aikenhead (2002) conducted a research and development study that aimed to investigate the issue of decolonizing school science and integrating Aboriginal science content into Canadian science education. The study found that teaching outdoors and involving students in exploring Aboriginal knowledge were effective teaching strategies that increase Aboriginal students' interest in science classes. The latter teaching strategy, as described in the study, emphasizes the coexistence of both sciences: Aboriginal and Western. This encourages Aboriginal students to engage in science classes, promotes their identity, and increases their self-esteem (Aikenhead, 2002). Besides the units designed for this study as teaching materials, a teacher guide was also developed with the assistance of Aboriginal educators from around the world, Aboriginal educators and Elders in the local community, and the researcher's experience and perspective. The aim of this guide is to provide teachers with more detailed information and background knowledge about Aboriginal science to support their teaching practices in classrooms. Some participants in the study already had the Aboriginal knowledge but used to question its authenticity, others learned this knowledge during their science classes in the study. In both situations, bringing up both sciences as coexistent endorsed the view of decolonizing school science which fosters economic advances, environmental awareness, and cultural survival for Canadian Aboriginal peoples.

Conclusion

Upon coming across the previously reviewed research, this study examined the effect of incorporating culturally relevant historical materials in science curriculum on Lebanese students' attitudes towards science.

To begin with, this study examined Lebanese students' attitudes *towards* science. As mentioned earlier, the study focused on the following four main constructs that define students' attitudes towards science: attitudes towards school science, attitudes towards scientists, interest in pursuing further science education and career, and impact of science on society. The subconstructs that delineate students' overall attitudes towards science were not defined; they were identified from participants' answers. In order to capture most of these subconstructs, this study followed a qualitative methodology. The researcher led focus group discussions with a list of prepared questions that target the four main constructs. The questions are direct, open-ended, and straightforward.

Second, this study took place in a Lebanese context. Lebanon's formal educational system is, one of the Arab countries that have been subject to a mandate rule, still mostly following the education system previously set by French rulers. The contributions of Arab scientists are very rarely referred to in the Lebanese science curriculum. Therefore, the researcher investigated the impact of including Arab scientists' contributions to optics in a physics unit on optics on Lebanese students' attitudes towards science.

It is acknowledged in the history of physics that the Arab scientist Ibn Sahl has arrived to the correct law of refraction 650 years earlier than Snell and Descartes (Al-Khalili, 2010; Smith, 2014). As stated by Smith (2014), Ibn Sahl is an Arab scholar who was very successful in Baghdad in the late tenth century. During his time, optics was one of the science disciplines that were not of interest to Muslim education. Scholars who were interested to pursue and carry out research in these disciplines had to find a patron. The patron represented a supporter to the selected scholars and provided them the freedom to research and write about any subject they were interested into. At the same time, many of these scholars worked as personal physicians for their patrons or astrologers; they had to fulfill any type of work assigned by their patrons. Scholars had to work hard in order to find and keep their patron. Their need for a supporter created a stressed, competitive, and sometimes aggressive environment between them. This necessity also encouraged deep learning, intellectual and academic purpose, professional dedication, and continuous innovation and creativity. Despite these conditions, Ibn Sahl was actively engaged in research on optics. He wrote a manuscript around 984 called *On the Burning Instruments*, which refers to lenses and mirrors that can be used to focus sunlight to create a hot spot. According to Al-Khalili (2010), it is important to note that although such burning methods had been known in ancient times, the work of Ibn Sahl is regarded as the first serious mathematical study of lenses for focusing light. The manuscript's pages were recently discovered in two different locations, one part in Damascus and the other in Tehran. After fitting the two pieces together and reconstructing the full original text, historians found that Ibn Sahl had the proposed the law of refraction that is now known as Snell's law. He correctly stated the law of refraction geometrically as the ratio of the sides of triangles of light rays, which is exactly equivalent to the law of refraction used by scientists nowadays. Thus, Ibn Sahl brought the analysis of lenses to a level of development not reached in Europe before the seventeenth century (Al-Khalili, 2010; Smith, 2014).

Accordingly, this study implemented focus group discussions and used an adopted analysis approach to characterize students' attitudes before and after an intervention in order to investigate the impact of a prepared physics unit on optics on Lebanese students' attitudes towards science. The prepared unit included the work and contributions of the Arab scientist Ibn Sahl. The methodology followed in this study will be elaborated in the next chapter.

CHAPTER III

METHODOLOGY

This study investigated the effectiveness of incorporating the contributions of Arab scientists into a unit on optics in grade 10 on Lebanese students' attitudes towards science. Students' attitudes were investigated using focus group discussions. This chapter includes the research questions and the analysis approach coupled with a description of its procedures and tools.

Research Questions

The two following questions were investigated in this study:

1. Does incorporating the contributions of Arab scientists into a unit on optics improve Lebanese students' attitudes towards science and in what ways?
2. How do Lebanese students perceive a culturally relevant science unit that incorporates reference to the contributions of Arab scientists?

Research Design

The research questions addressed in this study require in-depth understanding of Lebanese students' attitudes towards science and their views concerning the incorporation of Arab scientists' contributions in a physics unit on optics. According to Osborne and Collins (2001), the focus group provides a thorough reflection of participants' views in a dynamic, non-threatening social context. It also offers more reliable representations of individuals' views since they comprise the option not to respond to the question; unlike one-to-one interviews where participants sometimes feel the pressure to fake an answer in order to please the interviewer.

Focus group discussions took place before and after the completion of the physics unit on optics for two groups: an experimental and a control group. These discussions were audio taped and then transcribed. In order to help the researcher succeed in answering the research questions, the emerging data were coded. The researcher analyzed the data based on identified subconstructs and patterns in students' responses concerning their attitudes towards science.

Study Site and Participants

Study Site

In this study, data were collected from a public all-male high school located in the Southern suburb of Beirut. The school encompasses around 800 m^2 and serves around 800 students in grades 7 through 12. The school was established in 1998. In 2012, the school moved to a new building equipped with some technological facilities, such as: LCDs, computers, and one smart board in an interactive classroom. The students enrolled in this school are of low or middle socioeconomic status.

As a public school, it follows the National Lebanese curriculum and adopts its textbooks. This textbook includes reference to Western scientists and their contributions to modern science without mentioning the work of Arab scientists. For instance, in the unit on optics, the law of refraction that describes the relationship between the angles of incidence and refraction is credited to the Dutch astronomer Snellius and the French mathematician Descartes, even though it is documented that this law was first accurately described and stated by the Arab scientist Ibn Sahl at the Baghdad court in 984, six hundred and fifty years earlier than the European scientists (Al-Khalili, 2010). This historical fact is not taught to Lebanese students, and the work of Ibn Sahl remains unknown to them during their school years.

The selected high school serves only male students. This will create a natural grouping of the focus group discussions. First, several studies have reported the disparity between the responses of males and females to science and science education (Weinburgh, 1995). Furthermore, researchers reveal that the voice of female participants is often deprived in male-female group discourses (Tannen, 2007). Thus, in order to exclude the gender biases and accurately capture the views of the participants, it is better to organize separate focus groups for males and females (Osborne & Collins, 2001).

Selection of Participants and Population Characteristics

As stated by the director of the school, at the beginning of the school year students are randomly assigned to the different sections of their grade level. The school has seven sections of grade 10. Each section includes around twenty to twenty five students. Two randomly selected sections were used in this study; the sample consisted of thirty nine tenth grade male students enrolled into these two sections. Students in this grade level are provided the opportunity to choose whether to continue their education in science or humanities tracks starting in grade 11. Their choice will be recorded before and after the intervention to capture its possible impact on their views towards science education. The selected sections were randomly assigned to two groups: experimental group and control group. In both groups, two focus group discussions took place before and after the intervention.

Each focus group included nine to ten students. Before assigning students to the focus groups, the researcher asked the teacher to provide her with comments concerning all students' participation and abilities in their physics class. Following teacher's comments, the researcher assigned participants who accepted to take part of this study to the different focus groups. Each group consisted of a range of students having different abilities and participation level.

The researcher got permission from the director of the school, the physics coordinator, and the grade 10 physics teacher to carry out this study. The participants are of age 15-16 years old, thus both a child assent and a parental consent were required to approve their participation in this study.

Study Procedure

The researcher first discussed the intervention that will be applied in the experimental group with the teacher to explain and elaborate on the teaching strategies and scientific content of the lessons (see Appendices A, B, & C). A summary of the major similarities and differences in the lesson plans of both experimental and control groups is provided in Table 1.

The first two sessions were common for both experimental and control groups.

During the introductory session, the teacher drew students' attention to the importance of laws in science. Students constructed a concept map representing the relationships between law, theory, observation, and hypothesis. They further inferred the corresponding importance of laws in science. In the second session, the teacher gathered students' ideas about the appearance of bent objects in certain situations. Students observed and discussed the apparent bending of a pencil in a glass of water and that of a beam of light passing through a triangular prism. During this session, students had the opportunity to explain and justify their own understanding of the observed bent objects. The teacher provided a non-judgmental environment in order to encourage all students to share their ideas and possible explanations. As a conclusion, students determined the need for a scientific law.

Table 1.

A Summary of the Major Similarities and Differences in the Lessons Plans of Both Experimental and Control Groups

Number of Session	Experimental Group	Control Group
Session 1	Construction of a concept map representing the relationships between law, theory, observation, and hypothesis.	Construction of a concept map representing the relationships between law, theory, observation, and hypothesis.
	Identification of the importance of laws in science.	Identification of the importance of laws in science.
Session 2	Observation and discussion of the apparent bending of a pencil in a glass of water and that of a beam of light passing through a triangular prism.	Observation and discussion of the apparent bending of a pencil in a glass of water and that of a beam of light passing through a triangular prism.
Session 3	Examination of Ptolemy's data tables.	Identification of angles of incidence and angles of refraction
	Suggestion of the need for an applicable scientific law	Identification of the path of light as it passes through different mediums
Session 4	Exploration of the geometrical law of refraction proposed by Ibn Sahl	Introduction to Snell-Descartes law through laser light-semi-cylinder glass activity
Session 5	Introduction to Snell-Descartes law through laser light-semi-cylinder glass activity	Application of simple and direct problems on Snell's law
Session 6	Evaluation of the value of Ibn Sahl's work through a controversy debate	Solving problems of refraction in daily life situations using Snell's law

Following these two sessions, students in the control group were directly introduced to Snell-Descartes' law of refraction. After being introduced to angles of incidence and refraction, students in this group tried out the light - semi-cylinder glass activity (see Appendix B). Following this activity, the teacher explained Snell's law of refraction showing the relationship between angles of incidence and refraction in a given medium. Then, students in this group spent the remaining two sessions solving exercises as an application to Snell-Descartes' law of refraction.

As for the experimental group, students read, in the third session, a short text about the work of Ptolemy, the first scientist who tried to describe and inspect the phenomenon of refraction. They further examined his data tables concerning the angles of incidence and refraction of light passing through different media. Students detected the limitations of Ptolemy's data tables and implied the need for an applicable scientific law. Next, in the fourth session, students read a text about Ibn Sahl, an Arab scientist, who referring to Ptolemy's work, came up with the geometrical version of the law of refraction. They further reflected on the value of Ibn Sahl's work despite the fact that it did not contribute to the development of optics in the Latin West due to translation issues. After covering the geometrical law of refraction proposed by Ibn Sahl, students were introduced, in the fifth session, to Snell-Descartes law through a laser light-semi-cylinder glass activity (See Appendix C). Teacher noted that this law is equivalent to the one proposed by Ibn Sahl 650 years earlier. In the last session, students reflected on the issue of whether this law should be referred to as Snell's law or Ibn Sahl's law. The teacher led a structured controversy debate about the value of Ibn Sahl's work. One group supported the opinion of acclaiming the law of refraction as Snell's law while the other group adopted the opinion of attributing this law to Ibn Sahl. The teacher asked questions comparing Ibn Sahl's work to Snell's and questioning the importance of his proposed law despite it being unknown until recently. Students expressed their opinions, based on the adopted opinion of their group regarding his contributions that could have led to the development of lens theory. They further commented on whether his work should be appreciated, accredited, and/or recognized in the science field. At the end of this debate, students expressed their feelings towards this issue.

Data Collection Procedure

In order to gain insight into Lebanese students' attitudes towards science and their views concerning the incorporation of Arab scientists' contributions in a physics unit on optics, qualitative data are needed. The researcher was faced with two choices: individual interviews or focus group discussions. According to Osborne and Collins (2001), focus group methodology is a better choice than individual interviews. While individual interviews are extremely time-consuming and yield extensive data, focus group discussions (FGDs) are time efficient and provide an opportunity for participants to freely express their opinions and views in a dynamic non-threatening environment. Besides, unlike in individual interviews, participants in FGDs are not compelled to answer any question or feel pressured to make up a story just to please the interviewer. This increases the accuracy of the collected data about participants' views.

Focus Group Discussions

In this study, FGDs took place before the implementation of the intervention with the two groups separately in order to gain insight into participants' attitudes towards science on one hand, and their views regarding the contributions of Arab scientists on the other hand. The discussions took place in the school's conference room at an assigned time and lasted for 50 minutes. Following the recommendations of Rennekamp and Nall (2003), the researcher, being the moderator of these discussions, first welcomed the group, introduced herself, and informed the students that the discussions will be tape-recorded. The researcher described the purpose of this FGD, clarified why the participants have been selected to be part of this discussion, and declared the basic rules for participation. These include the following:

a. The questions have no right or wrong answers.
b. Each participant should feel free to communicate his own point of view.
c. Each participant is expected to listen and respect the different points of views of his peers.
d. Each participant has the right to legitimately express his opinion about the views of his peers (agree/disagree/give examples...)
e. All participants are expected to participate and share their points of views.
f. Side conversations are prohibited.
g. The moderator has the right to call on the non-participating members, or ask the members who shared lots of opinions to give chance to others.
h. The moderator will not include any name in her report. All the shared opinions, comments, and responses are confidential.

Following that, the discussion became focused and specific. The questions tackled the four constructs that are the focus of this study: attitudes towards school science, attitudes towards scientists, interest in pursuing further science education and career, and impact of science on society. (See Appendix D).

After the implementation of the intervention, FGDs took place again with both experimental and control groups separately. As in the first FGDs, the researcher welcomed the group, introduced herself, and informed the participants that the discussions will be tape-recorded. She explained the purpose of this FGD and restated the basic rules for participation. This time the discussions were focused on whether the intervention affected or changed their attitudes towards science within the four constructs that are the focus of this study.

Data Analysis

This study adopted Brown's (2006) iterative analysis methodology. In the aim of identifying the meaning and emerging themes in the collected data, different levels of analysis table were used. At the first level of analysis, all the focus group discussions were audio taped and then transcribed. The researcher used the collected data to identify summary codes from participants' answers related to the constructs that are the focus of this study. At the second level of analysis, the summary codes provided through data constituted the objects of analysis. Upon identifying summary codes from the collected data, the researcher grouped them into different categories. These categories represented the subconstructs of the research. Finally, the researcher sorted the identified subconstructs according to the four main constructs.

This study focused on four constructs related to attitudes towards science: attitudes towards school science, attitudes towards scientists, interest in pursuing further science education and career, and impact of science on society. These constructs might include various subconstructs. For instance, the construct "attitudes towards school science" might include the following subconstructs: perception of the quality of the science teacher, self-esteem in science classes, enjoyment of science classes, attitudes of peers and friends towards science, and the nature of the classroom environment. The subconstructs were identified from the collected data; some of the listed subconstructs were not raised in participants' answers and some new subconstructs were revealed in their answers.

After the intervention of the study was completed, the researcher transcribed the audio-taped focus group as a first level of analysis. This level included eight tables as follows: Pre-Experimental I, Pre-Experimental II, Pre-Control I, Pre-Control II, Post-Experimental I, Post-Experimental II, Post-Control I, and Post-Control II. Each table consisted of five columns: Line Number, Speaker, Transcript, Construct, and Code Summary.

Table 2.

Sample of Focus Groups Discussions' Transcript – Pre-Experimental Group I

Name	**Code**		**Description**	
Participant	PR		Male Lebanese Grade 10	
Fatima El-Ali	MO		Researcher (moderator of FGDs)	
Line Number	**Speaker**	**Transcript**	**Construct**	**Code Summary**
001	MO	How do you perceive science classes? Fun? Boring? Easy? Difficult? Interesting? Dull?		
002	PR1	Science classes are boring.		
003	MO	Why are they boring?		
004	PR1	All science classes are boring except laboratory sessions!	Attitudes towards school science	"All classes except labs are boring."
005	PR2	Yes, laboratory sessions are interesting and fun.	Attitudes towards school science	"Lab sessions are interesting and fun."
006	PR3	I don't like science classes, because I am not good in English. Most of the times, I don't understand the lesson.	Attitudes towards school science	"I don't like science classes because using English makes it difficult."

The first three columns are the mere transcript of the audio-tapes. In the Construct column, the researcher analyzed the statements in the transcript and categorized them into the four constructs that are the focus of this study. Lastly, the researcher objectively summarized the quotes of participants in the Code Summary column. As an example, table 2 represents a sample of focus groups discussions' transcript of pre-experimental group I. Proceeding with the analysis from these tables, the researcher categorized the summary codes into subconstructs as a second level of analysis. At this level, the analysis comprised two tables: Experimental Group and Control Group. All the summary codes from the focus group discussions in both experimental groups before and after the intervention were grouped and categorized into more general subconstructs. The same method was applied for the control groups. Table 3 displays a sample of the categorization of summary codes identified from the experimental group's transcript table. Following that, the researcher compiled all the identified subconstructs into a comparative table as a third level of analysis. This helped in sorting them in the four constructs that are the focus of this study.

In order to ensure reliability of data analysis, the physics class teacher was asked to examine the tables of the three level of analysis and reflect on the identified constructs and subconstructs. The teacher's role was to review the identified subconstructs coupled with their categorization into the four main constructs and suggest modifications accordingly. Following teacher's review, the study's results were organized as presented in the following chapter.

Table 3.

Sample of Summary Codes Categorization – Experimental Group

Experimental Group			
Pre-Intervention		**Post-Intervention**	
Summary Code	**Subconstruct**	**Summary Code**	**Subconstruct**
"All classes except labs are boring"	Lab sessions/ hands-on activities are motivating and interesting	"It's interesting that there are Arab Scientists"	Amazed Learning about and Arab Scientist
"Lab sessions are interesting and fun"		"Learning for the first time about a completely unknown Arab scientist was interesting"	
…		…	
"I like lessons that are life-related (electricity, forces, motion)"	Reference to real-life helps understanding	"I like learning the lesson as a story"	Learning the lesson as a story is appealing
"Real-life examples help me understand the lesson"		"Liked learning the law through a story"	
…		…	

CHAPTER IV

RESULTS

Through careful observations and focus group interviewing of study participants, rich and descriptive data were obtained. The collected data from both experimental and control groups provided information about participants' attitudes towards science based on the four constructs that are the focus of this study. These constructs are the following: attitudes towards school science, attitudes towards scientists, interest in pursuing further science education and career, and impact of science on society. Different subconstructs in all participants' focus group contributions before and after the intervention of the study are organized below in terms of experimental and control groups and the four constructs just listed.

Focus Group Discussions Before the Intervention of the Study

Participants' answers in focus group discussions before the intervention of the study revealed various subconstructs for each of the previously mentioned constructs. Most of the subconstructs were common between the two groups, while a few of them only emerged in one group.

Experimental Group

Participants in the experimental group engaged in well-organized focus group discussions. Their participation level was moderate and their answers were straightforward. The subconstructs identified from their answers are presented below, organized in terms of the four constructs that constitute the focus of the study.

Participants' attitudes towards school science.

Physics classes are challenging. A good number of participants expressed their dislike for physics classes. They stated that this is due to the challenges they face in these classes. Some participants viewed physics classes as hard, complicated, and boring. They said that they found difficulties in solving physics exercises that are challenging and require analysis as stated by one of the students that:"*I find it hard to solve the* (physics) *exercises or to analyze a certain experiment. The exercises are really complicated*". They also stated that they usually get exhausted from writing a lot teachers' explanation and supplementary elucidation of their physics book, as one of the student complained that he "*finds all physics classes hard"* and *"prefers literature classes".* In addition, many participants stated that they prefer literature classes since they are less challenging for them.

Physics laws are difficult and hard to understand. A number of participants declared that physics laws are difficult and hard to understand. For example, one student stated that he faces difficulties understanding a physics lesson if it has "*too many laws*". They also face difficulties memorizing the laws especially when there are numerous laws in a physics lesson. They don't even recognize the usefulness of some of the studied laws.

Lab sessions/hands-on activities are motivating and interesting. The majority of participants expressed interest in laboratory sessions and hands-on activities in science classes. One student expressed his interest in laboratory sessions as follows: "*Laboratory sessions are interesting because we are able to do the experiments ourselves rather than just reading about it in the book."* They expressed their preference of having an active role in a science session; in their opinion, this can be achieved in science laboratory or in class during hands-on activities. They enjoy such sessions and find them enjoyable as one student stated that he likes when "*the teacher brings instruments to the class and explains the lesson using the instruments.*"

Reference to real-life helps understanding. A good number of participants revealed that the use of real-life examples in science classes boosts their understanding of the lessons. For instance, one of the students commented that concrete examples help him understand science lessons. They also expressed their preference of topics that are related to their daily lives such as electricity.

The teacher makes me like/dislike science classes. The majority of participants stated that the teacher plays a crucial role in determining their interest in a science class. Their answers revealed that they prefer simple and direct ways of explaining over complicated and complex ways. One student explained the effect on teacher's way of explanation on his interest as follows: "*If the teacher knows how to explain the lesson in a simple way and does not make it complicated to understand, I will love the lesson.*" Participants are also encouraged by motivating teachers who push them to ask questions and praise their critical thinking. In addition, they mentioned that the teacher's own motivation and enjoyment of teaching the class influences their own enjoyment and interest in the class. For instance, one of the students stated the following: *"I used to dislike physics classes. But, my physics teacher last year made me like physics a lot! ….. She taught us with enjoyment and created a positive environment in the class."*

Science classes: preparation for engineering. A number of participants like science classes because they prepare them for engineering. They expressed their interest in electricity and mechanics chapters because they prepare them to become electrical and mechanical engineers.

New information in science classes are interesting. A few participants stated that they like learning new information in science classes. They view science classes as a valuable source to expand their knowledge and to learn completely new information.

Repetition helps understanding. A few participants mentioned that repetition of previously covered topics eases their understanding of science lessons. For example, a student claimed that the lesson is easy when it had been previously covered or as he stated "*not new*".

English language is a barrier. The issue of language of teaching was raised by one participant; he shared the difficulties he faces understanding the English language which hinders his understanding of science classes. Subsequently, this makes him lose interest in the class.

Participants' attitudes towards scientists.

Scientists: knowledgeable leaders and discoverers. A good number of participants viewed scientists as knowledgeable leaders and discoverers. One student claimed that scientists "*observe things, analyze, and interpret the information they have to make new discoveries*". They further described scientists as smart, hard-workers, and critical thinkers. Some participants also stated that "*scientists lead the development of a society*" without providing further elaborations.

Science field is always developing. A number of participants commented that science is continuously developing. They stated that science careers change with technological development and advances. They also highlighted the need for workers in science fields to stay up to date with these advances. For example, a participant mentioned that computer scientists need to be always aware of any new programs and updates: "*It* (science) *is a continuously developing field… For example, computer* *science is always developing. There are always updates and new programs. Computer scientists need to always be up to date."*

Participant's perception about continuing their education/career in science.

Science majors are demanding. A good number of participants consider science majors challenging and demanding. They stated that science majors are hard and require lots of studying. For instance, one student complained that he *"can't study that much"*. Besides, participants claimed that in order to succeed in a science major one must have critical thinking skills. They also specified that science majors require interpretive and analytical skills.

School grades influence choice of further science education. A few participants stated that their school grades and choices in continuing their education in science are directly correlated; the higher their grades are the more likely they are going to choose a science major at the university level. One student stated this correlation as follows: "*If I get good grades in science in the coming school years, I will choose a science major at the university."*

Science careers are challenging. A number of participants consider science careers hard and challenging. They stated that science careers such as careers in the medicine field are demanding and exhausting.

Science careers are highly valued. A few participants shared their high regard of science careers. They consider the science field very important because it opens up for wide career opportunities. They also appreciate these careers' high incomes.

Disinterest in science education and career. After sharing the advantages and disadvantages of science education and careers, a good number of participants expressed their interest in pursuing further education and career in the business and finance field. A few of them also showed interest in the army.

Science field is limited in our country. A few participants were interested in continuing their education and career in science fields, but shared their concerns regarding the availability of their intended majors in Lebanon. For instance, one student shared his interest in designing and building rockets and the need to travel in order to pursue his dreams as follows: "*I like to design and build rockets. It is my dream… I need to travel. I feel limited in our country… It is underdeveloped."* Another student expressed his interest in astronomy and shared the same concern as follows: "*I love astronomy, but I don't think it is available in Lebanon. If I want to become an astronomer I am going to travel abroad."*

Participants' perception about the impact of science on society.

Science knowledge: a need for life. A few participants shared their interest in science classes because they teach them about their bodies and surroundings. Moreover, a few participants highlighted human dependence on science and technology nowadays. For this reason, they consider having scientific knowledge and being aware of scientific information is a must.

Control Group

Participants in the control group also engaged in well-organized focus group discussions. Their participation level was acceptable and their answers were straightforward. The subconstructs identified from their answers are also organized in terms of the four constructs that constitute the focus of the study as follows.

Participants' attitudes towards school science.

Science classes are challenging. The majority of participants in the control group regarded science classes as challenging and hard. For them, science classes require intelligence, some analytical skills, and lots of studying. Moreover, one student stated that beside these requirements, science classes also "*require lots of focusing*".

Physics laws are difficult and hard to understand. A number of participants shared the difficulties they face in understanding physics classes. This is due to, as they have stated, the difficulties they face in understanding and memorizing the physics laws. They are also troubled by the good number of physics laws covered in their physics curriculum.

Lab sessions/hands-on activities are motivating and interesting. As in the experimental group, the majority of participants showed interest in laboratory sessions and hands-on activities in science classes. They stated that they enjoy laboratory sessions the most and find other science classes boring. They also like hands-on activities and find them interesting. For instance, one student stated that: *"Sometimes the teacher brings instruments to the class and we do a simple experiment. It is interesting and helps us understand better."*

Reference to real-life boosts interest in science class. A good number of participants stated that the use of real-life examples in science classes increases their interest in science lessons. They also expressed their preference of topics that are related to their daily lives such as body systems and gravity. For example, one student shared that: "*I only like science classes that are related to our daily lives… For example, learning about gravity, motion, pressure, body systems is good for us and beneficial."*

The teacher makes me like/dislike science classes. The majority of participants linked their interest in science classes to their science teachers. Most of them stated that science teachers' way of explanation play an important role in determining their interest in science classes. For instance, one participant stated that: "*If I like the teacher and his way of teaching, I will like the science class". * Moreover, participants added that their interest in science classes depends on teacher's motivation and own interest in the class. For example, one participant stated that: "*If the teacher enjoys teaching the science class, we all feel motivated and interested to learn. Maybe it is contagious!"*

Science classes: preparation for engineering. A few participants viewed science classes as preparation for engineering. They expressed their interest in them because they are interested in becoming engineers.

English language is a barrier. As in the experimental group, the issue of language was also raised by one participant; he expressed his dislike of science classes and claimed that this was probably due to the difficulties he faces with the English language.

Personal wellness affects interest in science class. One participant mentioned a correlation between his personal wellness and his interest in science classes. He stated that: "*If I have slept well that day, I will enjoy science classes. If not, I won't enjoy them"*.

Participants' attitudes towards scientists.

Scientists: knowledgeable leaders and discoverers. A few participants regarded scientists as the smart persons in the society who make new discoveries and lead its development. They highlighted scientists' analytical and interpretive skills.

Science field is always developing. A few participants raised the issue of continuous development in the science field. They provided examples from electronics they use in their daily life such as phones and computers.

Participant's perception about continuing their education/career in science.

Science majors are demanding. The majority of participants stated that science majors are demanding. For them, science majors require lots of studying and hard work. For instance, one student said that: "*You need to work hard to become a scientist… You must study a lot at the university!".* Moreover, participants claimed that science majors require thinking and analytical skills. These requirements hinder them from choosing a science major at the university. For example, one student stated that he will not choose a science major because he is "*not good in analyzing and solving problems*".

School grades influence choice of further science education. A few participants expressed their interest in further science education. However, they stated that their choice in continuing their education in the science field depends on their school grades in science classes. For instance, one participant shared that: "*I love engineering! But it depends on my grades. If I get good grades in Math I will become an engineer."*

Science careers are challenging. A few participants viewed science careers as challenging and complicated. In their opinion, scientists need to stay up to date with any new development or technological advances in their field. For example, one participant shared the challenges doctors face in their work. He stated that: "*All jobs related to science are complicated… Like the work of a doctor. They need to stay up to date with any development or any new medicine. If they have a patient with a new case. They need to study it in their books."*

Science careers are highly valued. A few participants shared their high regard of science careers. They view science careers as "*the most prestigious occupations in the society*". They also appreciate science careers' high incomes.

Interest/disinterest in science education and career. After discussing their opinions and views regarding science education and careers, a good number of participants expressed their interest in pursuing further education and career in the business and finance field. A few participants also expressed their interest in pursuing further education and career in the engineering field. For example, one student said that he loves to become a civil engineer because he likes "*making plans and drawing maps*".

Participants' perception about the impact of science on society.

Science knowledge: a need for life. A few participants shared their interest in science classes because they introduce them to their bodies and surroundings. They mentioned the following topics as examples: gravity, body systems, and motion.

Comparison of the Emerged Themes in Experimental and Control Groups

As the collected data reveals, most of the subconstructs that emerged in the focus group discussions before the intervention of the study were common between both experimental and control groups. Besides, a few subconstructs only emerged in one of the two groups. Reflecting on these results reveals that participants in both groups share mostly similar attitudes towards science in terms of the four constructs that are the focus of this study. Table 4 provides a summary of the similarities and differences in the emerged themes in both groups.

Focus Group Discussions after the Intervention of the Study

Following the intervention of the study, participants' answers in focus group discussions differed significantly between experimental and control groups. The subconstructs that emerged from the two groups are described in the following subsections.

Experimental Group

Participants in the experimental group engaged in more active and enthusiastic focus group discussions after the intervention than before. Their participation level was significant and their answers were quite detailed and elaborated. Despite being asked general and fairly generic questions, participants' answers were mostly focused on Ibn Sahl and Arab scientists in general. The emerged subconstructs identified from their answers were organized in terms of the four constructs that constitute the focus of the study as follows.

Participants' attitudes towards school science.

Amazed learning about an Arab scientist. The majority of participants showed interest in learning about an Arab scientist. They were surprised and interested in knowing that there are Arab scientists. For instance, one participant was stunned by the fact that "*Arabs have scientists!*". They also highlighted the fact that it is the first time that they learn about an Arab scientist.

Learning the lesson as a story is appealing. A good number of participants liked learning the lesson as a story. Some of them claimed that the story helped them understand the lesson. For example, one student stated that "*learning the law through a story was interesting and easy to understand*".

Table 4.

A Summary of the Similarities and Differences in the Emerged Subconstructs in Both Experimental and Control Groups Before the Intervention of the Study.

	Subconstructs	Experimental Group	Control Group
Attitudes towards school science	Physics classes are challenging.	✓	
	Physics laws are difficult and hard to understand.	✓	✓
	Lab sessions/ hands-on activities are motivating and interesting.	✓	✓
	Reference to real-life helps understanding.	✓	
	The teacher makes me like/dislike science classes.	✓	✓
	Science classes: preparation for engineering.	✓	✓
	New information in science classes are interesting.	✓	
	Repetition helps understanding.	✓	
	English language is a barrier.	✓	✓
	Science classes are challenging.		✓
	Reference to real-life boosts interest in science class.		✓
	Personal wellness affects interest in science classes.		✓
Attitudes towards scientists	Scientists: knowledgeable leaders and discoverers	✓	✓
	Science field is always developing.	✓	✓
Perception about continuing their education/career in science	Science majors are demanding.	✓	✓
	School grades influence choice of further science education.	✓	✓
	Science careers are challenging.	✓	✓
	Science careers are highly valued.	✓	✓
	Disinterest in science education and career.	✓	
	Science field is limited in our country.	✓	
	Interest/disinterest in science education and career		✓
Perception about the impact of science on society	Science knowledge: a need for life.	✓	✓

Interest/disinterest in history of science. A few participants shared their opinions regarding history of science. Some liked the history part and found it interesting while others did not like it.

Class group discussion is interesting. A few participants liked the activity of evaluating the work of Ibn Sahl in a class group discussion. They liked sharing their opinions and listening to their friends' opinions. For instance, one participant stated that: *"I liked the activity when we discussed the value of Ibn Sahl's work. It was interesting to know about each other's opinions."*

Hands-on activities are interesting. A few participants liked the hands-on activity that took place at the beginning of the covered lessons. They called it an "*experiment*" although it is considered as a hands-on activity.

Learning about the process of scientific discovery is interesting. A few participants shared their interest in learning about the process of a scientific discovery. They detected and discussed the steps that take place in a scientific discovery: raising questions, observing, analyzing, interpreting, and making conclusions. They also recognized that some of the conclusions made by scientists might change with time and development. In their opinion, learning about science discovery of the law improved their understanding. For example, one participant claimed that: "*We understood the law as a whole… What made scientists raise their question. What did they see… What did they do… Their trials and experiments to answer their question… Their conclusions… The law they discovered… How scientists who came after made changes to the previous law… it is the first time that I understand a law like this. I really like it!"*

Reading a text is an interesting activity. A few participants were interested in reading Ibn Sahl's text. They liked learning new information through reading.

Moreover, they enjoyed reading a text in a physics class, an activity they don't usually do.

Call for inclusion of Arab scientists in science curriculum. The majority of participants expressed the need to include Arab scientists in science curriculum. First, some of them complained about the exclusion of Arab scientists from their science textbooks. They objected to the inclusion of Snell's law without mentioning the work of Ibn Sahl. For instance, one participant complained that in their physics textbook "*They only talk about Snell, they don't mention Ibn Sahl*". Second, some of these participants showed enthusiasm to learn about the work and discoveries of other Arab scientists in their science classes. For instance, one participant said that: *"I loved learning about the work of an Arab scientist… Ibn Sahl… It seems that we have important scientists… I would love to learn more about their work and discoveries!"* Moreover, a few participants reflected on the inclusion of the work of Arab scientists in their science curriculum. They claimed that learning about Arab scientists "*increases the value of Arabs*".

Participants' attitudes towards scientists.

Interest in aspect of change in science. A few participants recognized the aspect of change in science. They expressed their interest in the development of scientists' thinking and views.

Feeling responsible towards Arab scientists. The majority of participants blamed Arabs for ignoring Ibn Sahl's work and other Arab scientists' discoveries. They also felt responsible towards introducing and revealing Arab scientists' work and discoveries to other societies. For example, one student stated that: "*We should tell* *everyone about our scientists and their discoveries. We should give them credit and value. We should reveal their work."*

Inspired by Ibn Sahl's characteristics. The majority of participants shared how Ibn Sahl inspired them to pursue their dreams and to continue their education and career in the science field. They liked his perseverance and hard work despite the difficulties he faced. They also admired his determination to fulfill his goals and ambitions. For example, one participant shared that: "*Ibn Sahl inspired me not to give up and to continue my education and career in the topic I like even if there is no support in my society. Or places to study or work in. I will work hard to become a rocket designer."*

Identifying Ibn Sahl's barriers. The majority of participants discussed the barriers faced by Ibn Sahl which hindered the recognition of his work. They all agreed to accuse his society. Participants stated that Ibn Sahl's discovery was lost because his society did not support or continue his work. They claimed that his name would have been known till now if his society dealt responsibly with his work.

Participant's perception about continuing their education/career in science.

Motivated to work in the science field. Upon learning about Ibn Sahl, a good number of participants expressed their motivation to work in the science field. For instance, one participant stated that: "*Learning about Ibn Sahl, an Arab scientist, motivated me to work in science and to become a scientist."* Moreover, participants' motivation encompassed not only their personal ambition to become scientists and discoverers but also to become key players in developing their country. For example, one student shared that they "*can start developing Lebanon step by step".*

Sharing big dreams. A good number of participants felt comfortable to share their personal big dreams. Upon learning about Ibn Sahl's work, participants were encouraged to become scientists and make new discoveries. For example, one participant stated that: *"I would like to continue my education in the science field because I want to discover something new like Ibn Sahl! I love discovering deep parts of oceans."* Moreover, participants were interested to pursue their interests despite their availability in Lebanon. For example, one participant shared that: *"I like nanophysics. I am interested in creating computer chips. I want to pursue my interests and work hard like Ibn Sahl."*

Participants' perception about the impact of science on society.

Society should support scientists. A few participants reflected on the important role of society in supporting scientists. They claimed that scientists' work can be influenced by their society. Furthermore, participants highlighted the role of societies in providing developed work centers for scientists. For example, one participant argued that: *"Countries should support scientists by encouraging them to work… providing them with work centers… buying for them developed equipment and materials."*

Acknowledging and valuing Arab scientists is important. The majority of participants reflected on the importance of acknowledging and valuing Arab scientists. They discussed the impact of acknowledging Ibn Sahl's work or other Arab scientists' work on future Arab generations. For instance, one participant commented that: *"This would have encouraged Arabs to continue their development till now also… Arabs would say that we have scientists and we can make discoveries… Not only the West have scientists and make discoveries."*

Developed countries are powerful. A few participants stated that developed countries are powerful. They claimed that the amount of development in science and technology influences the value of a society. Moreover, they discussed the power of a developed country in producing its own products and selling them to less developed countries. For example, one participant claimed that: *"A development of a country makes it strong and powerful… It will be able to produce and manufacture its own products and things it needs… it can also sell these products to other countries."*

Role and responsibility of scientists. The majority of participants reflected on the role and responsibility of scientists in leading the development of their society. They claimed that scientists increase the value of their society with their hard work and valuable discoveries. For instance, one participant stated that: "*I think scientists increase the value of their societies… By making discoveries… They can make new discoveries and lead the development of their country. Their country will become developed in science."*

Control Group

Participants in the control group displayed minimal interaction in focus group discussions following the intervention of the study. Their participation level was slight and their answers were short and simple. The few subconstructs that emerged from their answers were classified into the four constructs that constitute the focus of the study as follows.

Participants' attitudes towards school science.

Hands-on activities are interesting. As in the experimental group, a few participants liked the hands-on activity that took place at the beginning of the covered lessons. They called it an "experiment" although it is best considered a demonstration.

Interest/disinterest in history of science. The majority of participants disliked the history of science and found it useless to learn history in a physics class because as they claimed they "*just need to know laws and use them*". On the other hand, a few participants liked the part of history and showed interest in learning about the aspect change of science.

Interest in applying learned laws in real life situations. A few participants showed interest in solving real-life problems using the learned laws. They expressed their interest in knowing "*where to use learned laws*".

Participants' attitudes towards scientists.

Interest in aspect of change in science. A few participants recognized the aspect of change in science. They liked learning about the change of science laws with time and development.

Participant's perception about continuing their education/career in science.

Interest/disinterest in science education and career. Participants stated that the covered unit did not change their previous interest or disinterest in science education and career.

Comparison of the Emerged Themes in Experimental and Control Groups

It is evident that there are major differences between the subconstructs that emerged from participants' answers in focus group discussions following the intervention in the experimental and control groups. Unlike the similarities in the emerged subconstructs before the study's intervention in both groups, only few of them following the intervention were common. In the experimental group, most of the subconstructs were focused on Ibn Sahl and Arab scientists. Participants showed interest in acknowledging and learning about the work of Arab scientists. They also focused on its possible impact on society. Reflecting on these results reveals the impact of the intervention on participants' attitudes towards science in terms of the four constructs that are the focus of this study. A detailed discussion of the results will be provided in the following chapter. As for the control group, the subconstructs were not focused on a certain aspect. They were general and objective. These results reinforce the effectiveness of the intervention that took place in the experimental group. A list of the emerged subconstructs in both groups in each of the four constructs is illustrated in table 5. This list shows differences in the number and focus of emerged subconstructs in both groups.

Conclusion

The collected data reveals many similarities in the emerged subconstructs before the intervention of the study in both experimental and control groups. These similarities indicate that participants in both groups almost have similar perceptions and attitudes concerning the four constructs that are the focus of this study. Following the study's intervention, participants' perception and attitudes differed greatly between both groups. A detailed discussion of the study's result is provided in the following chapter.

Table 5

A List of the Emerged Themes in Both Experimental and Control Groups After the Intervention of the Study

	Subconstructs	
	Experimental Group	**Control Group**
Attitudes towards school science	Amazed learning about an Arab scientist.	Hands-on activities are interesting.
	Learning the lesson as a story is appealing.	Interest/disinterest in history of science.
	Interest/disinterest in history of science.	Interest in applying learned laws in real life situations.
	Class group discussion is interesting.	
	Hands-on activities are interesting.	
	Learning about the process of	

	scientific discovery is interesting.	
	Reading a text is an interesting activity.	
	Call for inclusion of Arab scientists in science curriculum.	
Attitudes towards scientists	Interest in aspect of change in science.	Interest in aspect of change in science.
	Feeling responsible towards Arab scientists.	
	Inspired by Ibn Sahl's characteristics.	
	Identifying Ibn Sahl's barriers.	
Perception about continuing their education/career in science	Motivated to work in the science field.	Interest/disinterest in science education and career.
	Sharing Big Dreams.	
Perception about the impact of science on society	Acknowledging and valuing Arab scientists is important.	
	Society should support scientists.	
	Developed countries are powerful.	
	Role and responsibility of scientists.	

CHAPTER V

DISCUSSION

The findings of this study demonstrate that the incorporation of the work of Ibn Sahl, an Arab scientist, has positively influenced participants' attitudes towards science. Moreover, the findings reveal the enthusiasm and interest of a number of Lebanese students concerning a culturally inclusive science curriculum. The study has a number of limitations that constrains its generalizability. Yet, its positive results set up a starting point for future research and support some recommendations for practice.

Change in Participants' Attitudes towards Science

With the increasing reliance of societies on science and technology, the drop in science experts negatively affects societies' economic futures (Hodson, 2003; & Simon & Osborne, 2010). Accordingly, there is a need to make school science more interesting and engaging for students. Students' attitudes towards science encompass several constructs (Gardner, 1975). The following four constructs constituted the focus of this study: attitudes towards school science, attitudes towards scientists, interest in pursuing further science education and career, and beliefs about the impact of science on society. A change in each of these constructs have been identified from participants' answers enrolled in the experimental group.

Change in Participants' Attitudes towards School Science

Before the implementation of the intervention, several subconstructs were revealed from participants' answers concerning their attitudes towards school science. A good number of participants viewed physics classes hard and challenging. A number of them complained that they face difficulties understanding and memorizing physics laws. They also get bored during physics sessions. Moreover, the majority of participants stated that they prefer literature classes over science classes. They also considered their science teachers key players in determining their interest in science classes. They claimed that their way of explaining science and motivation affect their interest in the class. A few participants mentioned that repetition of science topics improves their understanding. As for class activities, the majority of participants prefer hands-on activities and lab sessions over regular lecturing. Besides, a good number of them stated that the use of real life examples boosts their understanding of science lessons. Some participants shared their interest in learning new information in science classes. Participants interested in pursuing their education in engineering expressed their interest in science classes; they considered them a preparation phase for their future education and career. Besides, one participant complained that the English language hinders his understanding of science lessons.

Following the implementation of the study, participants showed persistent preference of hands-on activities over regular lecturing. All the other identified aspects from their answers concerning their attitudes towards school science were focused on the science content and curriculum. Despite previously complaining about the issue of English language hindering his understanding of science lessons, one participant in the experimental group showed interest in reading an English text in a physics class about the Arab scientist Ibn Sahl. He was very interested in the content of the text and did not object about the language barrier.

Moreover, as reviewed earlier, history of science makes science more attractive to many students (Matthews, 1994). This was evident in participants' answers demonstrating interest in history of science. Furthermore, the majority of participants were excited about learning about an Arab scientist. As stated by Key (2003), reading about scientists from their same ethnic group in science curricula helps students relate and connect with these scientists. This was evident in participants' answers. They felt connected to Ibn Sahl and showed enthusiasm to learn more about his life and characteristics. In addition, the majority of them considered the exclusion of Arab scientists' work from their science curriculum and the exclusive recognition of Western scientists' work a way of devaluing Arab scientists and societies. Thus, they called for the inclusion of all Arab scientists in the Lebanese science curriculum.

In addition, history of science improves students' contextual and procedural understandings (Mash & Wang, 2002). Even though the aim of this study was not assessing participants' level of understanding, traces of improvement in students' contextual and procedural understandings were apparent. A good number of participants explicitly stated that learning science lesson through a story is appealing to them. It helped them understand the lesson easily and without difficulties. In addition, upon learning about the process of work of Ptolemy, Ibn Sahl, and Snell, participants identified and discussed the steps in the process of scientific discovery: raising questions, observing, analyzing, interpreting, and making conclusions. They also showed good understanding of the tentative nature of conclusions made by scientists. This indicates an improvement in their procedural understanding. Moreover, participants showed interest in evaluating the work of Ibn Sahl through class group discussion. They reflected on the role of society and its influence on his work. This reveals an enhancement in their contextual understanding. This suggests a need for follow up studies to more directly assess the effect of culturally inclusive science curriculum on student's understanding of science lessons and aspects.

Change in Participants' Attitudes towards Scientists

Before the implementation of the intervention, a good number of participants viewed scientists as knowledgeable leaders. They described them as smart, hard-workers, and critical thinkers. Some also added that scientists lead their society without providing further details. In addition, a number of participants pointed out that science careers are continuously developing. They stressed the need for workers in the science field to stay up-to-date with any new advances or development. It is important to note that participants discussed their attitudes towards scientists in general terms without providing examples or further specification. For instance, when discussing the characteristics of scientists, participants did not share names of scientists nor refer to their stories of discoveries. Besides, when talking about continuous advances and development in science fields, they referred to developed countries as the source of these advances.

After the implementation of the study, participants' answers were focused on Ibn Sahl despite the fact that the questions were general and didn't specifically address this Arab scientist and his contributions. Their answers revealed their understanding and appreciation of human effort in science. As has been argued in the literature, history of science humanizes science education by portraying science as a human endeavor (Marsh & Wang, 2002). After covering the work of Ptolemy, Ibn Sahl, and Snell, participants showed a good understanding of particular scientists' roles in discovering scientific laws. Besides, a few of them recognized change in scientific knowledge as an important aspect of science. They expressed their interest in the development of scientists' thinking and views.

It is important to note that participants' answers were mainly focused on Ibn Sahl. The majority of participants shared their admiration of his perseverance and hard work despite the difficulties he faced. They also appreciated his determination to fulfill his goals and ambitions. Moreover, the majority of them highlighted the influence of society during Ibn Sahl's time on the preservation and publication of his work. They blamed Arabs for ignoring Ibn Sahl's work. They also felt responsible towards introducing and making Arab scientists' work and discoveries public. This is compatible with studies that stress on the great influence of incorporating and valuing the contributions of all groups to science on fostering students' cultural identity and enhancing their attitudes towards sciences (Matthews & Smith, 1994).

Change in Participants' Interest in Pursuing Further Science Education and Career

A good number of participants did not show much interest in continuing their education and career in science before the implementation of the study. They considered science majors demanding. They stated that science majors are hard and require lots of studying. A number of participants also viewed science careers as challenging. They claimed that science careers are also hard and exhausting. Moreover, a few participants added that their choice to continue their education and career in science fields depends on their school grades; the higher their school grades are the more likely they are going to choose a science major and career in the future. In addition, some participants discussed their high regard of science careers. They stated that these careers have high incomes and comprise the most important occupations in the society. As for the few participants who showed interest in pursuing their education and career in science, their concerns were the availability of their intended majors in Lebanon. They claimed that science field is limited in Lebanon.

Following the implementation of the intervention, a number of participants showed interest to continue their education and career in science. Their motivation was triggered after learning about Ibn Sahl's characteristics and work. This is consistent with Ninnes' (2003) finding that the inclusion of indigenous scientists' contributions to modern science in science curricula serve as cultural representations for students. This seemed to enhance their attitudes towards science and increase their attitude toward science disciplines and possibility of and a career in science (McKinley, 2007). Participants referred to Ibn Sahl as a role model and an inspiration who motivated them to pursue their personal ambitions and work hard to become successful scientists and discoverers "*like him*". Their enthusiasm and motivation led them to express their desire to serve their societies. For instance, one participant shared that they "*can start developing Lebanon step by step*". Participants were encouraged to improve their country and become key players in leading its development in the future.

Furthermore, their encounter with an Arab scientist in their science curriculum encouraged a good number of participants to want to achieve more in science. They overlooked their previous concerns about the limitations they face in Lebanon and felt comfortable sharing their personal big dreams. For instance, one participant shared his interest of becoming a nanophysicist despite its unavailability in Lebanon. This is compatible with studies in the literature that point to the effect of the presence or lack of cultural images in the curricula on students (Key, 2003; McKinley, 2007). Indigenous students who had not encountered in their school years or read about a scientist from their own ethnic group may internalize the notion that they are incapable of doing science (Key, 2003). This might affect not only their personal image, but also their attitudes towards science and future educational and career choices (McKinley, 2007; McKinley & Gan, 2014). The presence of Ibn Sahl, an Arab cultural image, in the implemented science lessons motivated a good number of participants to pursue their education and career in the science field.

Change in Participants' Perception about the Impact of Science on Society

Before the implementation of the intervention, a few participants viewed science knowledge essential for their daily life. They claimed that science classes are important because they teach them about their bodies and surroundings. Moreover, they highlighted the current human dependence on science and technology which increases the necessity of having a scientific knowledge and awareness. Their discussion was brief and limited in scope. They presented good understanding of the necessity of having science knowledge with the increasing dependency on technology in the society. However, they did not mention the level of development in Lebanese society nor the impact of science and scientists on it.

After the implementation of the intervention, participants elaborated more and presented a better understanding of the interrelation between society and scientists. A few participants reflected on the important role of society in supporting scientists. Again, as in previous questions, their discussion was focused on Ibn Sahl and Arab scientists. This demonstrates that including the work of Ibn Sahl in their physics lessons triggered their Arab identity and increased their concerns and interest in valuing the work of Arab scientists. They reflected on the importance of acknowledging and valuing Arab scientists. They suggested that this will have a positive impact on future Arab generations; they will be encouraged to make discoveries and work in the science field like for example Ibn Sahl. Their focus on Ibn Sahl and their discussions concerning future Arab generations imply that the covered lessons fostered participants' Arab identity. Analogously, it is stated in the literature that culturally inclusive science curriculum promotes indigenous students' identity (Aikenhead, 2002; McKinley, 2007). Moreover, some participants went further in the discussion and talked about the power and value of developed countries. They stated that developed countries are powerful and have the ability to produce and sell their own products. Furthermore, the majority of participants reflected on the important role of scientists in leading the development of their society. Their arguments were thoughtful and reflective. They discussed scientists' responsibilities and the value of their hard work and discoveries. Participants' answers showed their feelings of responsibility towards changing and leading the development of Lebanon. Their aims after the implementation of the study were high and prominent. This matches previously reviewed studies stating that culturally inclusive science curriculum stimulates indigenous students' aspirations and ambitions (Aikenhead, 2002; McKinley, 2007).

Summing up the Effects of a Culturally Inclusive Science Curriculum

Aikenhead (2002) states that culturally inclusive science curricula encourage students to engage in science classes, promote their identity, and increases their self-esteem. Similarly, after learning about Ibn Sahl's work and his contributions to science, participants demonstrated an increased interest in school science, a promoted Arab identity and fostered ambitions and aspirations. Furthermore, participants raised a demand to value the work of Arab scientists and to incorporate it in Lebanese science curriculum.

First, participants' answers revealed an increased interest in school science. The inclusion of the work of Ibn Sahl, an Arab scientist, boosted their motivation to learn about scientists in general and Arab scientists in particular. Furthermore, participants called for the inclusion of Arab scientists in Lebanese science curriculum. They complained about the exclusion of Arab scientists' work from their science textbooks. Reflection on these findings reveals that students feel connected when learning about a scientist from their own society or culture. This connection increases their interest to pay attention, listen, focus, and interact during science lessons. It will also trigger their critical thinking; their interest will surpass their classroom setting to encompass their society and culture. Participants' great interest in the lesson about Ibn Sahl led them to detect his characteristics and interpret the barriers which hindered the recognition of his work.

Second, learning about Ibn Sahl's work triggered participants' Arab identity and encouraged them to share big ambitions. Participants were encouraged by Ibn Sahl's characteristics. They admired his perseverance and hard work despite the difficulties he faced in his society. They also identified the factors that hindered the recognition of his work. Participants further considered him an inspiration who increases their self-image as Arabs in the science domain. They stated that science discoveries are not exclusively the result of Western societies' work. Participants translated this confidence by sharing their enthusiasm to work in the science field and their big ambitions and dreams to become science discoverers. Reflecting on these findings, Ibn Sahl represents a cultural inspiration for participants. Upon being exposed to Arab scientists, students will internalize their capability of becoming scientists and making discoveries. This will boost their interest in science classes and motivate them to pursue their education and career in the science field.

Finally, participants stressed on the importance of recognizing and valuing Arab scientists' work. They felt responsible towards Arab scientists and blamed their societies for devaluing their work. Participants acknowledged the importance of recognizing Arab scientists' work. They stated that this recognition will have a positive impact on future Arab generations. Moreover, they claimed that this will motivate them to work in the science field and make scientific discoveries like their ancestors. As a reflection on these findings, the exclusive recognition of Western scientists in their science curriculum annoys participants. Their call for the inclusion of Arab scientists' work in their science textbooks demonstrates that students are proud of their ancestors; they consider them a cultural treasure that needs to be valued and recognized by all societies.

Limitations of the Study

This study has several limitations which suggest caution in interpreting the significance of its findings. The limitations include the type of the research, the size of the study sample, and the use of focus group discussions as a methodology.

First, this study is a qualitative research which limits its reliability. The study is based on subjective and interpretive data. In the aim of increasing the reliability of the collected data and assuring consistency in the analysis, the class's teacher checked the transcribed data and the inferred subconstructs. This enhances the study's reliability but does not eliminate the problems associated with reliability of subjectively interpreted data.

Second, the sample size for this study was thirty nine participants, divided among two groups (control and experimental group). It is a small sample which limits the generalizability of the findings. Thus, expanding the sample size and broadening the representation of the population of Lebanese students are needed. Moreover, participants were all male which means the study was missing the voice of female Lebanese students. Research points to differences in attitudes towards science and interest in science topics between male and female students (Simon & Osborne, 2010; Tytler, 2014). For instance, participation in physical sciences and engineering is persistently dominated by males (OECD, 2006). Therefore, investigating the effect of culturally inclusive science curriculum on female Lebanese students' attitudes can differ from its effect on male Lebanese students' attitudes to and interest in science and scientists. Studies focusing on the voice of female Lebanese students can convey their views and opinions. Moreover, a follow up study could examine the effects of incorporating reference to female Arab scientists in the curriculum. They might represent a cultural model and an inspiration for female Lebanese students. In addition, participants in this study shared the same social background and context. Their background might have an effect on their positive interaction with valuing Arab scientists' work. It is important to explore the attitudes of Lebanese students coming from diverse social backgrounds existing in Lebanon. This is important because some Lebanese subcommunities don't feel related to their Arab identity and culture; they tend to have preferences for Western societies. Their more or less "Westernization" might affect their response to such an intervention focusing on valuing Arab culture and fostering Arab identity. This might provide a stronger view and richer guidance for

Lebanese curriculum developers concerning the issue of incorporating the contributions of Arab scientists in Lebanese science curricula and science textbooks.

Third, the study used focus group discussions in order to have a thorough reflection of participants' views in a dynamic, non-threatening social context. Moreover, this offered more reliable representations of participants' views since they comprise the option not to respond to the question; they did not feel the pressure to fake an answer in order to please the interviewer. Yet, some participants may be more comfortable expressing their opinion in individual interviews. They might find focus group discussions intimidating and may feel pressured to agree with the dominant view in the group discussion. Moreover, the moderator's phrasing of questions along with follow up questions in order to lead and to keep the discussions relevant to the study's topic might influence participants' responses and shape the study's results.

Implications for Future Research

The findings of this study provide insights into the effect on Lebanese students' perceptions of science and scientists after the incorporation of Arab scientists' contributions in the science curriculum. The enthusiasm of participants and their call for integration of Arab scientists' work into Lebanese science curriculum can trigger further wider-scale research to investigate and elaborate on Lebanese students' opinions about the inclusion of Arab scientists in science curriculum. In addition, this study demonstrates the positive effect of this inclusion on Lebanese students' attitudes towards science. Participants showed increased interest in school science, a triggered Arab identity and fostered ambitions and aspirations. They further raised a demand to value the work of Arab scientists. This can set up a starting point for future studies to investigate its effect not only on students' attitudes but also their identities, self-esteem, understanding or other factors. Moreover, the small sample of this study prohibit generalizations. Yet, it sets a starting point for further research to be carried out on a larger scale in the Lebanese community. Generalizations from such studies might also trigger other Arab communities to broaden this research field in order to thoroughly understand the effects of including the work of Arab scientists in the science curricula of Arab nation. They might be interested in replicating these studies to explore their findings in their own communities.

Implications for Practice

In order to enhance Lebanese students' attitudes towards science and increase the number of science experts in Lebanese community, the following recommendations follow from this study: (a) review of Lebanese science curriculum developers of similar studies that investigate the incorporation of Arab scientists' work in science classes on Lebanese students, in order to weigh the advantages and disadvantages of such incorporation and to decide and consider whether to include their work in science curricula and science textbooks, (b) encourage science teachers to expand their knowledge about Arab scientists, and (c) for teachers to include them in their lessons, pointing out their important contributions to science both locally and internationally.

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Appendix A

Lesson Plans (Sessions 1+2): Experimental and Control Groups

Prepared by: Fatima El-Ali

Class: Grade 10

<u>Lesson 1 (experimental + control)</u>

Topic:

The importance of laws in science.

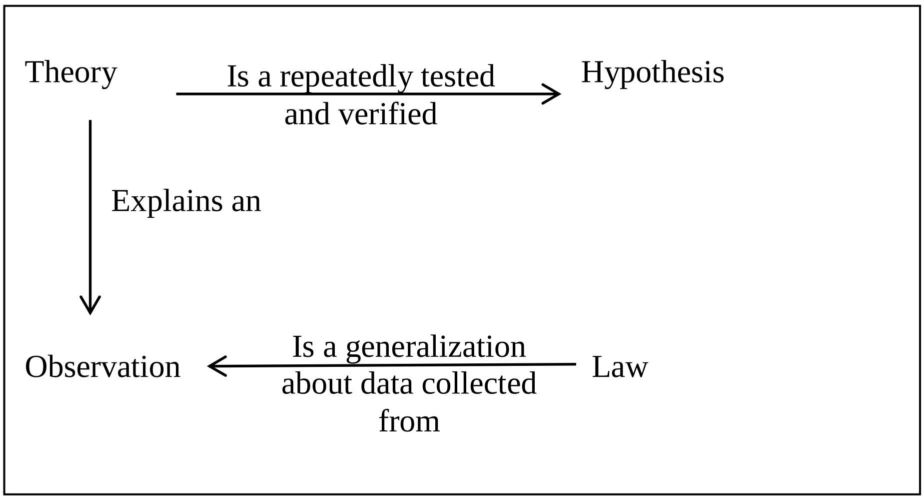
Time allotted for lesson:

50 minutes.

Short description of lesson:

Students will examine the definition of laws and infer their corresponding importance in science. First, they will work in groups to construct a concept map specifying the relationships between: law, theory, observation, and hypothesis. Then, upon a class presentation and discussion of their maps, teacher will guide students to come up with a generalization of what a law is. Following that, students will read the conventional definition of scientific laws. Teacher will further present several examples of physics laws and lead a class discussion of their importance.

Scientific content and concepts:



In science, the term law usually refers to a generalization about data. It helps predict an observable occurrence by specifying the relationship between the associated variables.

The teacher will provide students with different examples of scientific law (or might use the examples they have suggested); for instance, Coulomb's law, Ohm’s law, and Joule’s law.

The teacher will elaborate on the importance of scientific law in predicting the occurrence of certain natural events and regulating humans’ actions accordingly.

Learning outcomes:

Students will be able to:

- State the characteristics of a scientific law.
- Name examples of scientific laws in physics.

- Explain the importance of laws in science.

Students' prerequisite knowledge and skills:

- Ability to construct a concept map.
- Initial differentiation between observation, hypothesis, law, and theory.

Instructional Procedures:

Time	Activity
5 mins	Teacher will present a quick review of concept maps and how to construct it. Then, Lesson I - Handout (1) will be introduced. The teacher will read and elaborate on the task based on students' needs.
15 mins	Students will work in groups of three/four to construct a concept map relating and linking observation, hypothesis, law, and theory.
10 mins	Each group will pick a speaker who will present their concept map to the class. The students will ask clarifying questions or evaluate the presented concept map. Throughout this discussion, the teacher will guide students to come up with a generalization of what a law is by highlighting their relevant ideas.
10 mins	Lesson I – Handout (2) will be introduced. Teacher and students will read the conventional definition of laws in science. Students will be asked to state examples of laws previously covered in physics.
10 mins	Teacher will lead a class discussion of the importance of laws in science + wrap up.

Student products:

Students will construct a concept map relating and specifying the relationships between observation, hypothesis, law, and theory.

Assessment of learning outcomes:

Concept maps will be used as a formative assessment.

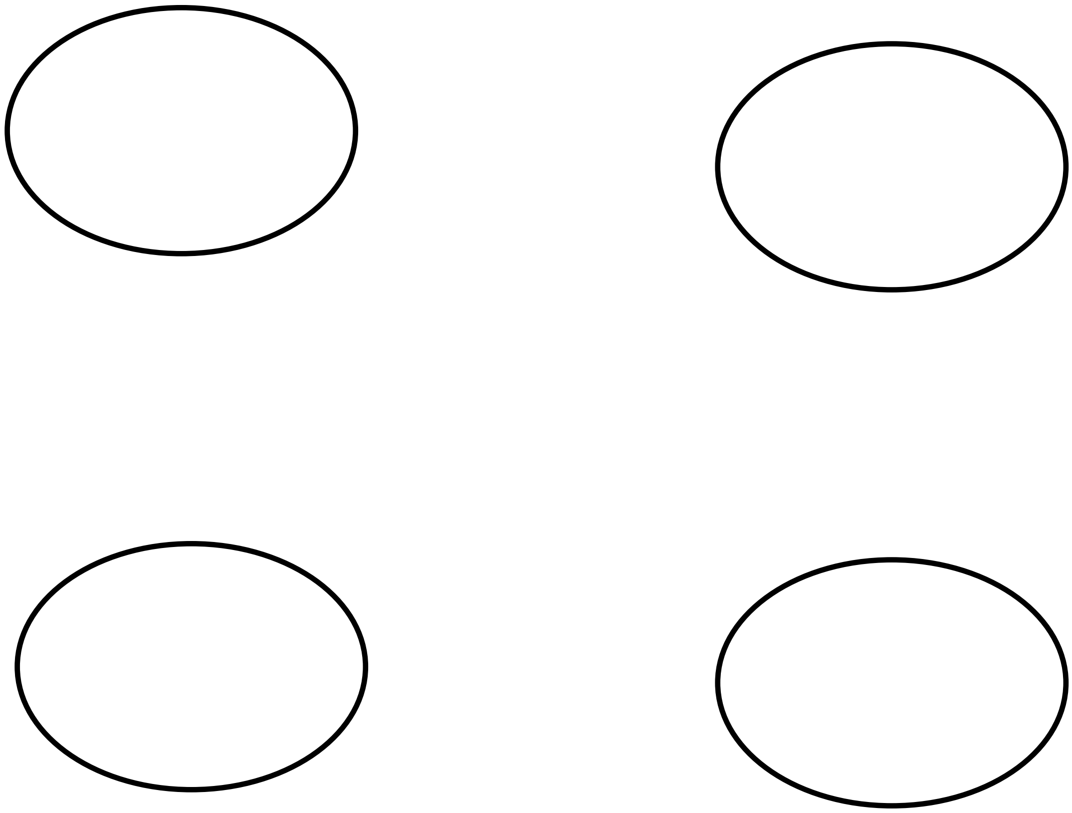
Lesson I - The Importance of Laws in Science

Handout (1)

<u>Concept Map</u>

Constructing a concept map is a great visual tool that can help you illustrate the relationships between different concepts!

Fill in the bubbles below with the following terms: law, theory, observation, and hypothesis. Next, draw connecting lines between these bubbles. Write on each connecting line the relationship between the connected terms.



Lesson I - The Importance of Laws in Science
Handout (2)

What is a Scientific Law?

Read the following two definitions of a scientific law:
A scientific law is:

Definition I:
A theoretical principle deduced from particular facts, applicable to a defined group or class of phenomena, and expressible by a statement that a particular phenomenon always occurs if certain conditions be present. (Oxford English Dictionary as quoted in Futuyma, 1979).*

Definition II:
*A set of observed regularities expressed in a concise verbal or mathematical statement. (Krimsley, 1995)**.*

Name examples of scientific laws in physics:

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References:

* Futuyma, D. J. (1979). Evolutionary Biology. Sinauer Assoc.
** Krimsley, V. S. (1995). Introductory Chemistry, 2nd Ed. Brooks/Cole Publishing Co., Pacific Grove.

Lesson 2 (experimental + control)

Topic:

The apparent bending of an object.

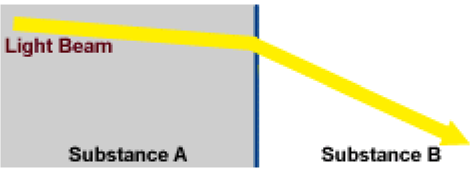
Time allotted for lesson:

50 minutes.

Short description of lesson:

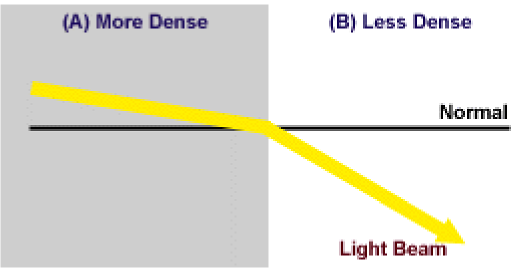
Students will work in pairs to describe and try to explain the bending of a pencil in a glass of water and the bending of light upon passing through a triangular prism. They will present and share their ideas. Following that, students will have a class discussion suggesting what scientists would do after observing the apparent bending of an object. After being introduced to scientific laws in the previous session, students will suggest that a scientific law is needed.

Scientific content and concepts:



The bending of light as it passes from one medium to another is called refraction.

The angle and wavelength at which the light enters a substance and the density of that substance determine how much the light is refracted.
When light passes from a more dense to a less dense substance, (for example passing from water into air), the light is refracted (or bent) away from the normal.



The normal is a line perpendicular (forming a 90 degree angle) to the boundary between the two substances. The bending occurs because light travels more slowly in a denser medium.

Another example of refraction is the dispersion of white light into its individual colors by a glass prism. As visible light exits the prism, it is refracted and separated into a magnificent display of colors.

Each color from the original beam of light has its own particular wavelength (or color) and each wavelength is slowed differently by the glass. The amount of refraction increases as the wavelength of light decreases. Shorter wavelengths of light (violet and blue) are slowed more and consequently experience more bending than do the longer wavelengths (orange and red).
Retrieved from http://ww2010.atmos.uiuc.edu/(Gl)/guides/mtr/opt/mch/refr/more.rxml

Learning outcomes:

Students will be able to:

- Describe the apparent bent pencil in a glass of water.

- Describe the bending of light when passing from air to glass/glass to air.

Students' prerequisite knowledge and skills:

- Ability to write expressive observations related to a specific scientific phenomenon.
- Recognize the importance of laws in science.

Instructional Procedures:

Time	Activity
5 mins	Lesson II – Handout (1) will be introduced. Teacher will present the materials needed for this experiment (pencil and a beaker filled with water). Teacher will explain that students are requested to describe first the shape of the pencil, and then describe its shape after placing it in water. Finally, students are asked to give a possible reason for the apparent change of the pencil's shape.
15 mins	Students will work independently to fill out the task's sheet trying to describe and explain the apparent bending of the pencil. Then, with the guidance of the teacher, students will share their answers. The teacher will highlight the most relevant answers by writing them on the board.
5 mins	Lesson II – Handout (2) will be introduced. Teacher will present the materials needed for this experiment (flashlight and a triangular prism). Teacher will explain that students are requested to turn on the flashlight and hold the prism in the light beam. They are asked to describe the path of light and elaborate on a reason that caused the change in its pathway.
15 mins	Students will work independently to fill out the task's sheet trying to describe and explain the apparent bending of light as it passes through the triangular prism. Then, with the guidance of the teacher, students will share their answers. The teacher will highlight the most relevant answers by writing them on the board.
10 mins	Teacher will lead a class discussion suggesting what scientists would do to explain the apparent bending of objects and inferring that a scientific law is needed.

Student products:

Learners will write down their observations and explanations on the task sheet.

Assessment of learning outcomes:

Anecdotal records of students' skills in explaining the phenomenon of the bending of light.

Lesson II – The Apparent Bending of an Object
Handout (1)
Pencil in a Glass of Water Experiment

1- Describe the shape of the pencil you are using in this experiment.

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2- Describe the shape of the pencil when placed in the glass of water. Compare it to its original shape.

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3- Give a possible reason that caused the apparent change in the shape of the pencil when placed in the glass of water.

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Lesson II – The Apparent Bending of an Object
Handout (2)

The Passage of Light through a Triangular Prism

1- Describe the path of light when it passes through the triangular prism.

2- Elaborate on a possible reason that caused the change of light's pathway as it passed through the triangular prism.

Appendix B

Lesson Plans (Sessions 3+4+5+6): Experimental Group

Prepared by: Fatima El-Ali

Class: Grade 10

Lesson 3 (experimental group)

Topic:

Ptolemy's refraction of light experiment

Time allotted for lesson:

50 minutes.

Short description of lesson:

Students will be introduced to the work of the first scientist who tried to describe and inspect the phenomenon of refraction: Ptolemy. They will be informed of his experiments; following the teacher's small introduction of his work and how he recorded data of the angles of incidence and refraction of light passing from one medium to another, students will examine and try to qualitatively describe his data tables. Following the presentation of their ideas, the teacher will lead a guided discussion about the limitations of Ptolemy's tables and infer the need for a definite applicable law.

Scientific content and concepts:

In the domain of mathematical optics, Ptolemy's study of refraction is regarded as his most original contribution. Ptolemy states that both reflection and refraction involve the breaking of visual rays. He notes that this breaking is due to the interruption of visual ray caused by the resistance of certain bodies to its penetration. A body's surface is reflective when it resists penetration completely causing the visual ray to be fully broken by rebound. This rebound is incomplete in refraction because the body is transparent and its surface's resistance is only enough to deflect the visual ray as it passes through. Therefore, Ptolemy views refraction as a special case of reflection in which the rebound of visual rays is incomplete.

Going further into refraction, Ptolemy presents experimental efforts to measure the angles of refraction for given angles of incidence when the visual ray refracts from air-water, air-glass, and water-glass. He measured values of the angle of refraction, the angle made by the ray as it passes into the other medium with the perpendicular at the point of refraction for a complete series of incident angles increasing by 10 degrees.

Angle of Incidence in Air (degree)	Angle of refraction in Water (degree)
10	8
20	15.5
30	22.5
40	29
50	35
60	40.5
70	45.5
80	50

Angle of Incidence in Air (degree)	Angle of refraction in Glass (degree)
10	7
20	13.5
30	19.5
40	25
50	3
60	34.5
70	38.5
80	42

Angle of Incidence in Water (degree)	Angle of refraction in Glass (degree)
10	9.5
20	18.5
30	27
40	35
50	42.5
60	49.5
70	56
80	62

Despite his experimental efforts, Ptolemy failed to identify the quantitative relationship between the angles of incident and refraction.

Learning outcomes:

Learners will be able to:

- Elaborate on Ptolemy's attempt to explain and analyze the passage of light from one medium to another.
- Predict the direction of the bending of light as it passes through different media.
- Identify the angles of incidence and angles of refraction.

Students' prerequisite knowledge and skills:

- Read and decode data from a given table.
- Describe patterns in a given data table.

Instructional Procedures:

Time	Activity
15 mins	Lesson III – Handout (1) will be introduced. Teacher and students will read the text that introduces students to the work of Ptolemy, the first scientist who explained this phenomenon. Teacher will further define angles of incidence and refraction.
15 mins	Lesson III – Handout (2) will be introduced. Students will work

	independently to solve it. They will read and describe patterns in Ptolemy's tables representing data of angles of incidence and refraction of light passing from: air to water, air to glass, and water to glass.
10 mins	Teacher will lead a class discussion of students' answers in order to come up with approved collective answers.
10 mins	Teacher will lead a discussion about the limitations of Ptolemy's tables inferring the need for an applicable scientific law.

Student products:

Learners will complete the task's worksheet about reading and decoding Ptolemy's tables.

Assessment of learning outcomes:

Lesson III – Handout (2) number (I) will be used as a formative assessment.

Lesson III – Ptolemy's Refraction of Light Experiment
Handout (1)
Ptolemy: A Historical Overview

Ptolemy was a Greco-Roman mathematician, astronomer, geographer, and astrologer. In optics, Ptolemy wrote about properties of light, including reflection, refraction, and color. His study of refraction is regarded as his most original contribution in the domain of mathematical optics.

Ptolemy views refraction as a special case of reflection. He states that both reflection and refraction involve the breaking of light. He notes that this breaking depends on the resistance of a body's surface to the penetration of light. Complete reflection occurs when the body's surface completely resists the penetration of light. On the other hand, refraction occurs in transparent bodies. The surface's resistance of these bodies is only enough to bend the light as it passes through the body.

Going further into refraction, Ptolemy presents experimental efforts to measure the angles of refraction for given angles of incidence when the visual ray refracts from air-water, air-glass, and water-glass. He measured values of the angle of refraction, the angle made by the ray as it passes into the other medium with the perpendicular at the point of refraction for a complete series of incident angles increasing by 10 degrees.

The below table represents Ptolemy's collected data of angles of incidence and refraction when light passes from air into water.

Angle of Incidence in Air (degree)	Angle of refraction in Water (degree)
10	8
20	15.5
30	22.5
40	29
50	35
60	40.5
70	45.5
80	50

Lesson III – Ptolemy's Refraction of Light Experiment
Handout (2)
Ptolemy's Data Tables: Angles of Incidence and Refraction

I- Observe the tables below representing data of angles of incidence and refraction of light passing from one medium to another. Then, answer the questions that follow.

Angle of Incidence (degree)	Angle of Refraction (degree)
10	8.0
20	15.5
30	22.5
40	29.0
50	35.0
60	40.5
70	45.5
80	50.0

TABLE 1 Air- Water

1- **Choose an appropriate title for the above table.**

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2- **Referring to the table above, describe the relationship between the angles of incidence and refraction of light passing from air to water.**

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Angle of Incidence (degree)	Angle of Refraction (degree)
10	7.0
20	13.5
30	19.5
40	25.0
50	30.0
60	34.5
70	38.5
80	42.0

TABLE 2 Air- Glass

1- **Choose an appropriate title for the table above.**

____

____

2- **Referring to the table above, describe the relationship between the angles of incidence and refraction of light passing from air to glass.**

____

____

____

____

Angle of Incidence (degree)	Angle of Refraction (degree)
10	9.5
20	18.5
30	27.0
40	35.0
50	42.5
60	49.5
70	56.0

80	62.0

TABLE 3 Water- Glass

1- **Choose an appropriate title for the table above.**

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2- **Referring to the table above, describe the relationship between the angles of incidence and refraction of light passing from air to water.**

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II- Provide a generalization from the data tables above describing the relationship between angles of incidence and refraction of light upon passing from one medium to another.

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<u>Lesson 4 (experimental group)</u>

Topic:

Ibn Sahl's law of refraction

Time allotted for lesson:

50 minutes.

Short description of lesson:

Upon inferring the need for an applicable scientific law of refraction, students will work in groups to review previous sessions' handout (2) trying to make a generalization over Ptolemy's data tables. The teacher will guide a class discussion where groups share their suggested generalizations. Then, students will be introduced to the first scientist who referring to Ptolemy's work, came up with the law of refraction: Ibn Sahl, an Arab scientist.

Scientific content and concepts:

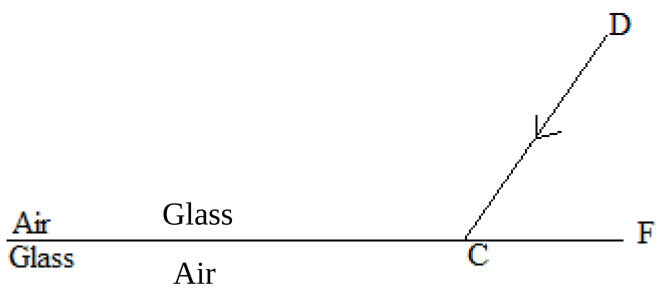
Ibn Sahl is a scholar who flourished in Baghdad in the late tenth century. He wrote a treatise around 984 called "On the Burning Instruments", which refers to lenses and mirrors that can be used to focus sunlight to create a hot spot. It is important to note that the work of Ibn Sahl is regarded as the first serious mathematical study of lenses for focusing light. His manuscript's pages were recently discovered in two different locations, one part in Damascus and the other in Tehran. The following power point presentation provides an explanation of Ibn Sahl's proposed geometrical law of refraction.

Ibn Sahl's Proposed Law of Refraction

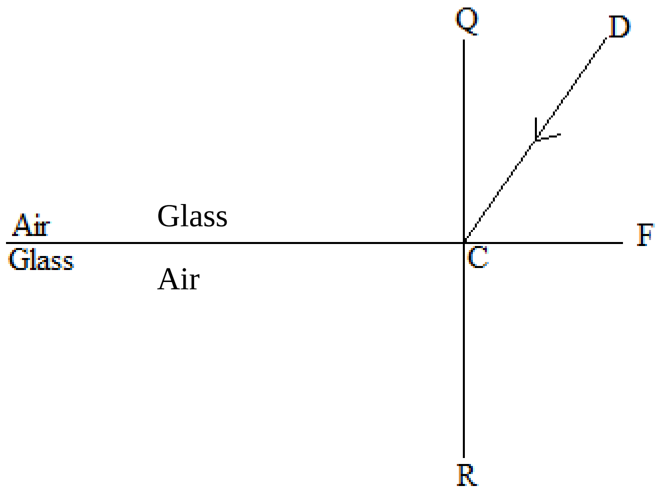
Prepared by:
Fatima El-Ali

- GF represents the interface between glass and air

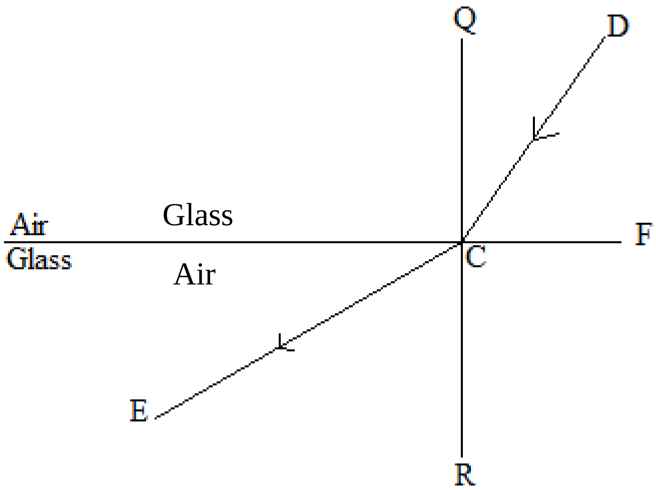
- DC represents a ray passing through the interface from the denser (glass) into the rarer medium (air)



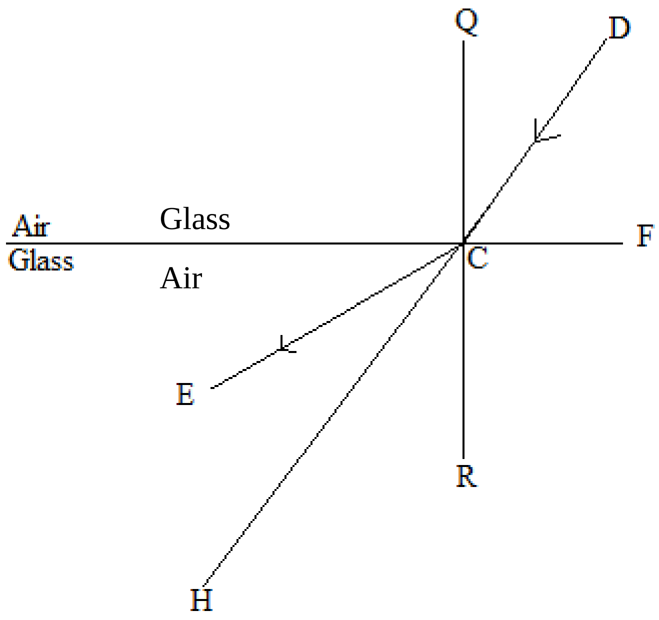
- QCR represents the normal to the interface at point C



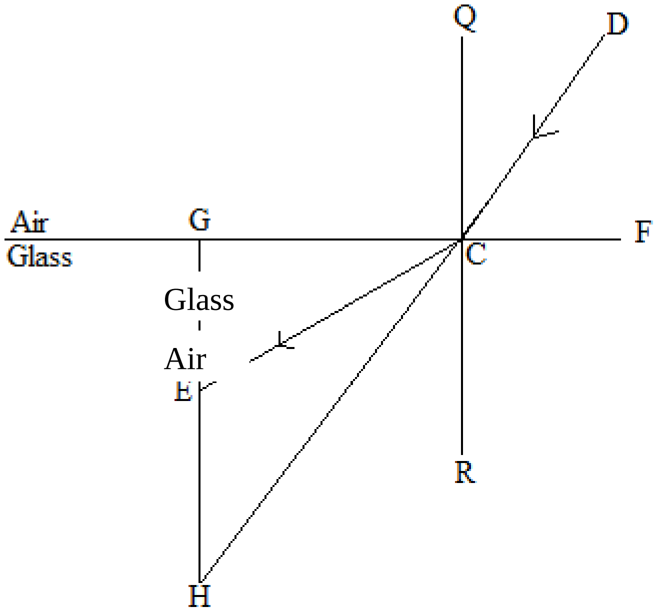
- The ray DC will be refracted away from the normal QCR along CE



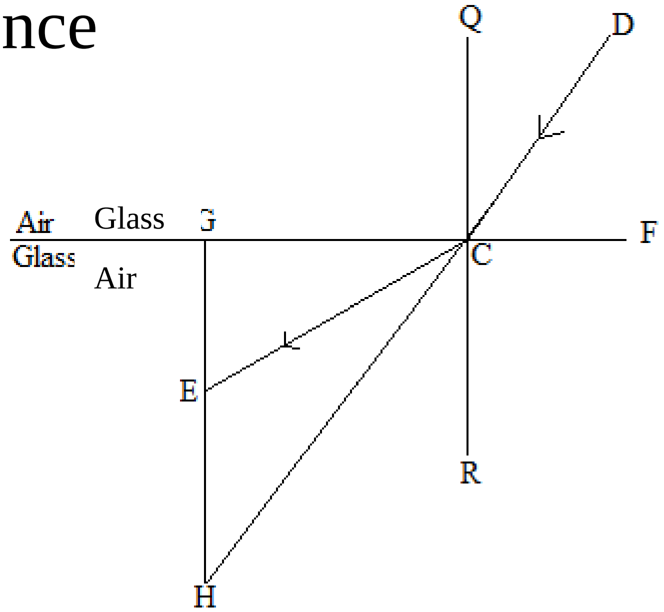
• Let CH the continuation of the incident ray DC

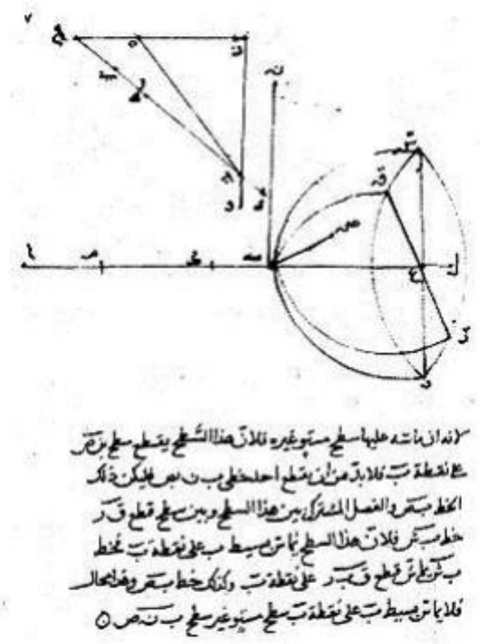


- Drop normal GEH through CH and CE to intersect them at points H and E



- Ibn Sahl proves that the ratio between CH and CE remains constant no matter the angle of incidence





Reproduction of a page of Ibn Sahl's manuscript showing his discovery of the law of refraction

Ibn Sahl brought the analysis of lenses to a level of sophistication not reached in Europe before the seventeenth century. However, his relevant work was never translated, so he could contribute nothing to the development of lens theory in the Latin West.

Learning outcomes:

Learners will be able to:

- State Ibn Sahl's contributions to the study of refraction.
- Describe Ibn Sahl's geometrical generalization.

Students' prerequisite knowledge and skills:

- Retrieve information from a text.
- Answer comprehension questions related to a text.
- Differentiate between angles of incidence and refraction.

Instructional Procedures:

Time	Activity
5 mins	Students will review in groups their generalization from Ptolemy's data tables using their Lesson III – Handout (2).
5 mins	In a class discussion, students will share their generalizations from Ptolemy's data tables. Teacher will reinforce the importance of having an applicable scientific law.
15 mins	Lesson IV - Handout (1) will be introduced. Students will read a text about Ibn Sahl as an introduction to his work. They will also answer comprehension questions.

10 mins	Teacher will lead a class discussion of the read text. Students will share their answers. The teacher will further explain and elaborate on the answers when needed.
10 mins	Using the power point presentation specific for students, teacher will explain Ibn Sahl's geometrical version of the law of refraction.
5 mins	Teacher will reinforce the idea that despite the fact that Ibn Sahl came up with the law of refraction, his work was never translated and thus did not contribute to the development of optics. As a wrap up, students will comment on the value of his work despite the fact that it did not contribute to the development of optics in the Latin West due to translation issues.

Student products:

Students will answer comprehension questions about Ibn Sahl's text.

Assessment of learning outcomes:

Comprehension questions task sheet will be used as a formative assessment.

Lesson IV – Ibn Sahl's Law of Refraction
Handout (1)
Ibn Sahl: An Arab Scholar

Some science disciplines, such as Optics, were not of interest to Muslim education. Scholars who were interested to pursue and carry out research in these disciplines had to find a patron. The patron represented a supporter to the selected scholars and provided them the freedom to research and write about any subject they were interested into. At the same time, the scholars had to complete any work assigned by their patrons. For instance, many scholars worked as personal physicians for their patrons or astrologers. The need for a supporter created a stressed, competitive, and sometimes aggressive environment between scholars. Scholars had to work hard in order to find and keep their patron. In addition, this environment encouraged deep learning, intellectual and academic purpose, and professional dedication. It required continuous innovation and creativity.

Ibn Sahl is an Arab scholar who was very successful in Baghdad in the late tenth century. He was actively engaged in research on optics. He wrote a manuscript around 984 called *On the Burning Instruments*, which refers to lenses and mirrors that can be used to focus sunlight to create a hot spot. It is important to note that although such burning methods had been known in ancient times, the work of Ibn Sahl is regarded as the first serious mathematical study of lenses for focusing light. The manuscript's pages were recently discovered in two different locations, one part in Damascus and the other in Tehran. After fitting the two pieces together and reconstructing the full original text, historians found that Ibn Sahl had proposed the law of refraction that is now attributed to another scientist from the Latin West. Ibn Sahl correctly stated the law of refraction geometrically as the ratio of the sides of triangles of light rays, which is exactly equivalent to the law of refraction used by scientists nowadays. Thus, Ibn Sahl brought the analysis of lenses to a level of development not reached in Europe before the seventeenth century. However, his relevant work was never translated, so he could contribute nothing to the development of optics in the Latin West.

1- Referring to the above text, describe Ibn Sahl's characteristics as an Arab scholar who explored the domain of optics.

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2- List Ibn Sahl's contributions in the domain of optics previously mentioned in the text.

3- As stated in the text, Ibn Sahl's work did not contribute to the development of optics in the Latin West. In your opinion, does this affect the value of his work? Justify your answer.

<u>Lesson 5 (experimental group)</u>
Topic:

Snell-Descartes law

Time allotted for lesson:

50 minutes.

Short description of lesson:

After covering the geometrical law of refraction proposed by Ibn Sahl (the ratio of the sides of triangles of light rays), students will be introduced to Snell-Descartes law through an activity. The teacher will present the trigonometric ratio stated by Snell and confirmed independently by Descartes 650 years following Ibn Sahl. Students will solve exercises as an application to this law. Teacher will end the session with the issue of whether this law should be referred to as Snell's s law or Ibn Sahl's law.

Scientific content and concepts:

http://farside.ph.utexas.edu/teaching/302l/lectures/node128.html

Experiment: https://www.youtube.com/watch?v=yfawFJCRDSE

Learning outcomes:

Learners will be able to:

- State Snell's law.
- Apply the law of refraction to solve given exercises.
- Compare and reflect on the credits of the law of refraction given to Snell-Descartes and the credits of the same law given to Ibn Sahl.

Students' prerequisite knowledge and skills:

- Record measurements in a table.

Instructional Procedures:

Time	Activity
5 mins	Lesson V – Handout (1) will be introduced. Teacher will explain the task where students have to vary the angle of incidence of light ray coming from the laser light and reaching the semi-circular glass and measure the angle of refraction accordingly. Students have to record their data in a table.
15 mins	Students will work in groups to complete Lesson V – Handout (1) recording data of angles of incidence and refraction.
15 mins	Teacher will explain Snell's law and note that it can accurately predict the value of their recordings and measurements.
10 mins	Lesson V – Handout (2) will be introduced. Students will work independently to apply Snell's law with different values of angles of incidence and refraction.
5 mins	Wrap up. Teacher will note that Snell's law is equivalent to Ibn Sahl's generalization and ask students to think whether the credit should go to Ibn Sahl or to Snell as a preparation for next session.

Student products:

Students will fill a table with measurements of angles of incidence and refraction.

Assessment of learning outcomes:

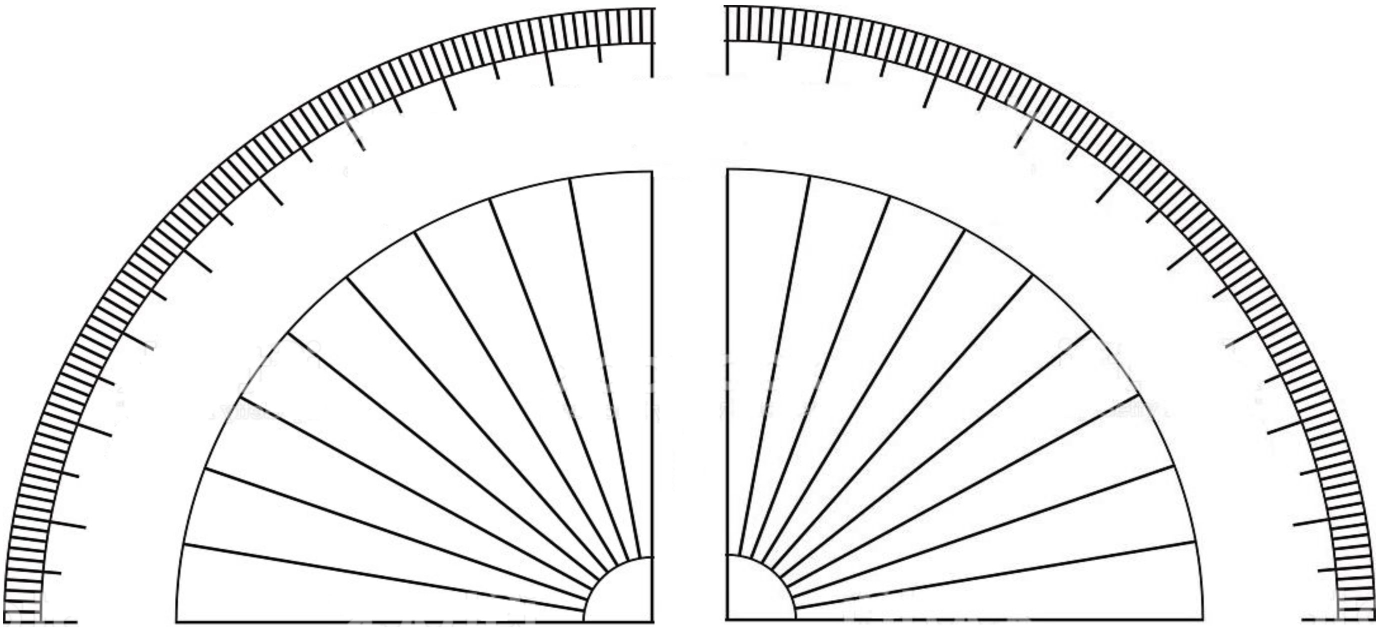
Lesson V Handout (2) will be used as formative assessment.

Lesson V – Snell-Descartes Law

Handout (1)

Laser Light-Semi-Circular Glass Activity

Write down the measurements of the angles starting from 0^0 at the vertical axis. Place your semi-circular glass at the horizontal axis. Vary the angle of incidence of light ray reaching your semi-circular glass and measure its corresponding angle of refraction. Record your data in the below table.



Angle of Incidence	Angle of Refraction

Title of table: ______________________________

Lesson V – Snell-Descartes Law

Handout (2)

Application on Snell's Law

Snell's Law describes how light bends when traveling from one medium to the next. Mathematically, it is stated as:

$$n1 \sin \theta 1 = n2 \sin \theta 2.$$

n1 represents the index of refraction in medium 1, and θ1 represents the angle the light makes with the normal in medium 1.

Medium	Index of Refraction (n)
Air	1
Ice	1.31
Water	1.33
Glass	1.52

Use Snell's law to solve the following problems:

1) What is the angle of refraction in an ice cube if the angle of incidence in air is 48˚?

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2) An underwater swimmer looks up toward the surface of the water on a line of sight that makes an angle of 25˚ with a normal to the surface of the water. What is the angle of incidence in air for the light rays that enter the swimmer's eye?

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3) A ray of light in air strikes a block of quartz at an angle of incidence of 30˚. The angle of refraction is 20˚. What is the index of refraction in quartz?

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Lesson 6 (experimental group)

Topic:

Comparing Ibn Sahl’s geometrical generalization to Snell’s law

Time allotted for lesson:

50 minutes.

Short description of lesson:

Upon being familiar with Ibn Sahl, the teacher will lead a structured controversy debate about the value of his work. One group will support giving credits to Ibn Sahl and valuing his work. The other group will question the value of Ibn Sahl’s contribution to the science field.

The teacher will ask questions comparing Ibn Sahl’s work to Snell’s and questioning the importance of his proposed law despite it being unknown until recently. Students will express their opinions, based on the opinion their group has to adopt, regarding his contributions that could have led to the development of lens theory and whether his work should be appreciated, accredited, and/or recognized in the science field. Moreover, they will express their feelings towards this issue.

Learning outcomes:

Learners will be able to:

- Compare Ibn Sahl’s geometrical generalization to Snell’s law
- Evaluate the value of Ibn Sahl’s work despite the fact that it did not contribute to the development of lens theory in the Latin West.

Students’ prerequisite knowledge and skills:

- Being knowledgeable of group discussions’ protocols and regulations.

Instructional Procedures:

Time	Activity
5 mins	Teacher will introduce the task to students
20 mins	Each group will adopt one opinion, discuss together to think about supportive arguments to defend it. Then, the two groups will share their arguments and the teacher will lead the discussion.
20 mins	The groups will swap the adopted opinions, discuss together to think about supportive arguments to defend it. Then, they will share their arguments and the teacher will lead the discussion.
5 mins	Wrap up; students will express their feelings toward this issue.

Student products:

Students will write in groups their arguments supporting the adopted opinion.

Assessment of learning outcomes:

Anecdotal records of students’ argumentative competencies.

Handout (1)

Controversy Debate: Argument #1

Ibn Sahl's discovery of the law of refraction has little or no historical importance. This is because Snell and Descartes did not refer to his work when they came up with the law of refraction. In other words, Ibn Sahl's work did not contribute to the development of lens theory in modern science.

We support this opinion, because

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Lesson VI – Comparing Ibn Sahl's Geometrical Generalization to Snell's Law

Handout (2)

Controversy Debate: Argument #2

Europeans argue whether the law of refraction should be referred to as Snell's law or Decartes' law. There is no doubt that the real credit should go to Ibn Sahl. He arrived to the correct trigonometric ratio 650 years earlier than Snell and Descartes.

We support this opinion, because

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Appendix C

Lesson Plans (Sessions 3+4+5+6): Control Group

Prepared by: Fatima El-Ali

Class: Grade 10

Lesson 3 (control group)

Topic:

Introduction to Refraction.

Time allotted for lesson:

50 minutes.

Short description of lesson:

Students will build on the previous session and identify with the guidance of their teacher the angles of incidence and refraction. They will further be introduced to Snell-Descartes law through a laser light-semi-cylinder activity.

Scientific content and concepts:

https://www.youtube.com/watch?v=plZocHWpFhk

Learning outcomes:

Students will be able to:

- Define refraction.
- Identify incident and refracted rays.
- Identify angles of incidence and refraction.
- Specify the path of light away from/towards the normal as it passes through different mediums.

Students' prerequisite knowledge and skills:

- Compare indices of different mediums.

Instructional Procedures:

Time	Activity
5 mins	Recap from previous session; Teacher will state that the apparent bending of light is the phenomenon of refraction.
15 mins	Teacher will use the pencil-glass of water example to define and explain the normal, and angles of incidence and refraction. Students will specify whether the pencil bends towards the normal or away. The teacher will elaborate on the refraction of light from dense-light/light-dense mediums and its refraction away from/towards the normal.
15 mins	Lesson III – Handout (1) will be introduced. Students will specify whether light will refract away from/towards the normal when passing from different mediums based on their indices.
10 mins	With the guidance of the teacher, students will detect and state examples of refraction in their classroom.

5 mins	Wrap up; teacher will reinforce the need for an applicable scientific law.

Student products:

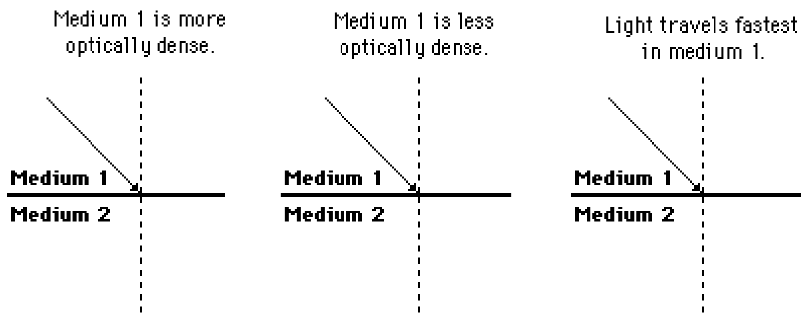
Students will specify the path of light when passing from different media (away from/towards the normal).

Assessment of learning outcomes:

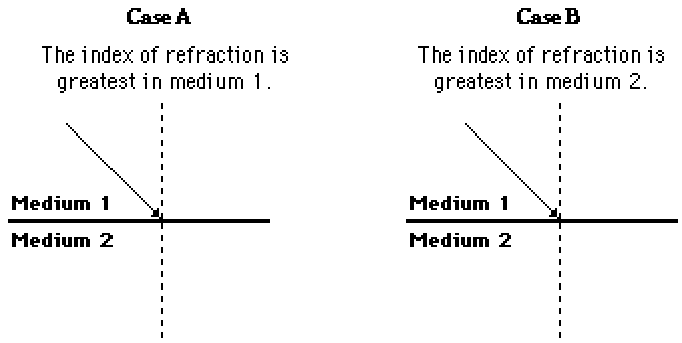
Lesson III Handout (1) will be used as a formative assessment.

Lesson III – Introduction to Refraction
Handout (1)
The Direction of Refracted Ray

1) **Draw in each diagram, the refracted ray showing the appropriate direction of bending (towards or away from the normal).**



2) **For the following two cases, state and justify whether the ray of light will bend towards or away from the normal upon crossing the boundary.**



Case A:

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Case B:

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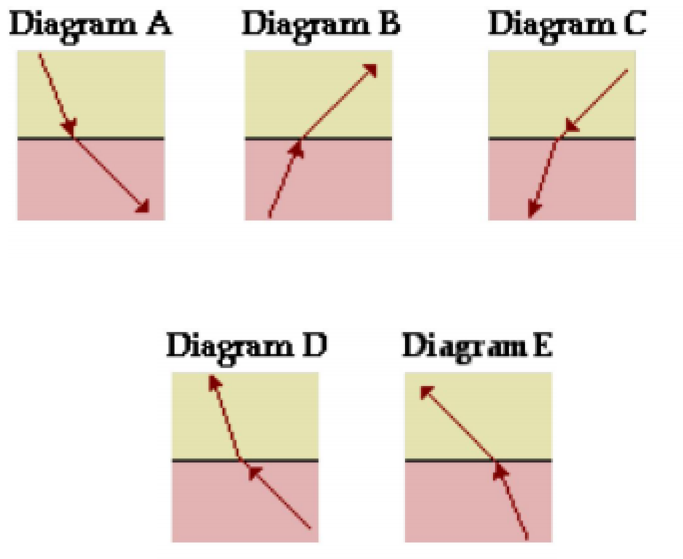
____

3) **Consider the refraction of light in the five diagrams below. Circle the case/s in which the light is bending towards the normal line.**



Lesson 4 (control group)

Topic:

Snell-Descartes law

Time allotted for lesson:

50 minutes.

Short description of lesson:

After being familiar with the phenomenon of refraction, students will be introduced to Snell-Descartes law through laser light - semi-cylinder activity. The teacher will present the trigonometric ratio stated by Snell and confirmed independently by Descartes.

Scientific content and concepts:

http://farside.ph.utexas.edu/teaching/302l/lectures/node128.html

Experiment: https://www.youtube.com/watch?v=yfawFJCRDSE

Learning outcomes:

Learners will be able to:

- State Snell's law.
- Reflect on the uses of Snell's law in daily life.

Students' prerequisite knowledge and skills:

- Record measurements in a table.

Instructional Procedures:

Time	Activity
5 mins	Lesson V – Handout (1) will be introduced. Teacher will explain the task where students have to vary the angle of incidence of light ray coming from the laser light and reaching the semi-circular glass and measure the angle of refraction accordingly. Students have to record their data in a table.
20 mins	Students will work in groups to complete Lesson V – Handout (1) recording data of angles of incidence and refraction.
15 mins	Teacher will explain Snell's law and note that it can accurately predict the value of their recordings and measurements.
10 mins	Wrap up; students will reflect on the uses of Snell's law in daily life.

Student products:

Students will fill a table with measurements of angles of incidence and refraction.

Assessment of learning outcomes:

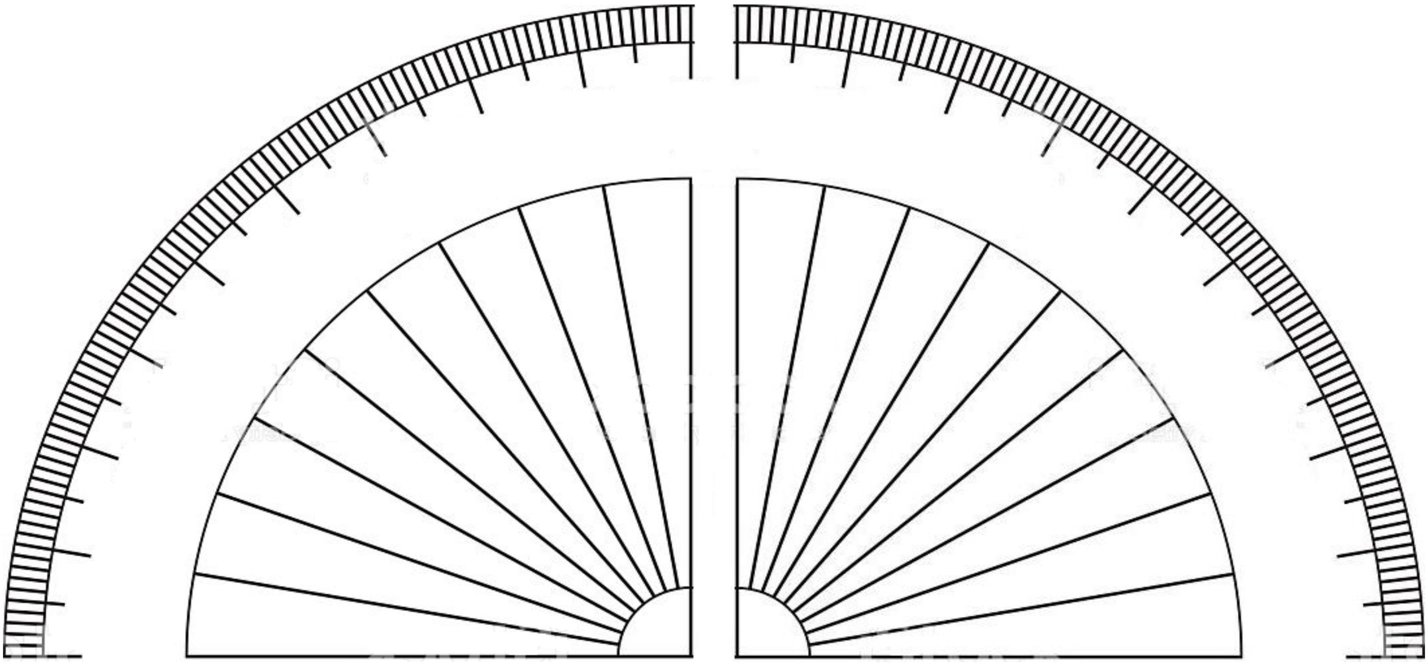
Lesson VI Handout (1) will be used as formative assessment.

Lesson IV – Snell-Descartes Law

Handout (1)

Laser Light-Semi-Circular Glass Activity

Write down the measurements of the angles starting from 0^0 at the vertical axis. Place your semi-circular glass at the horizontal axis. Vary the angle of incidence of light ray reaching your semi-circular glass and measure its corresponding angle of refraction. Record your data in the below table.



Angle of Incidence	Angle of Refraction

Title of table: ____

Lesson 5 (control group)

Topic:

Direct Application on Snell's Law.

Time allotted for lesson:

50 minutes.

Short description of lesson:

Students will work in pairs to solve given exercises as a direct application on Snell's law.

Scientific content and concepts:

http://farside.ph.utexas.edu/teaching/302l/lectures/node128.html

Learning outcomes:

Students will be able to:

- Use Snell's law to solve a given exercise.

Students' prerequisite knowledge and skills:

- State Snell's law.

Instructional Procedures:

Time	Activity
10 mins	Lesson V- Handout (1) will be introduced. The teacher will do the first question on the board asking for and eliciting on students' answers. The teacher will clarify the needed steps to solve such exercises using Snell's law.
20 mins	Students will work in pairs to complete and solve the rest of the worksheet using Snell's law. Teacher will pass by to check students' answers.
15 mins	Based on students' answers, teacher will choose some of the exercises to be solved on the board. Students will be encouraged to ask clarification questions.
5 mins	Wrap up; teacher will summarize how to use Snell's law to solve such exercises.

Student products:

Students will use Snell's law to solve given exercises.

Assessment of learning outcomes:

Lesson V – Handout (1) will be used as a formative assessment.

Lesson V – Snell-Descartes Law

Handout (1)

Application on Snell's Law

Snell's Law describes how light bends when traveling from one medium to the next. Mathematically, it is stated as:

$$n1 \sin \theta 1 = n2 \sin \theta 2.$$

n1 represents the index of refraction in medium 1, and θ1 represents the angle the light makes with the normal in medium 1.

Medium	Index of Refraction (n)
Air	1
Ice	1.31
Water	1.33
Ethanol	1.36
Glass	1.52

Use Snell's law to solve the following problems:

1) What is the angle of refraction in an ice cube if the angle of incidence in air is 48˚?

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2) An underwater swimmer looks up toward the surface of the water on a line of sight that makes an angle of 25˚ with a normal to the surface of the water. What is the angle of incidence in air for the light rays that enter the swimmer's eye?

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3) A ray of light in air strikes a block of quartz at an angle of incidence of 30˚. The angle of refraction is 20˚. What is the index of refraction in quartz?

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4) An incident ray in air is approaching the boundary with an unknown material at an angle of incidence of 61.6^0 . The angle of refraction is 41.4^0 . Determine the index of refraction of the unknown material.

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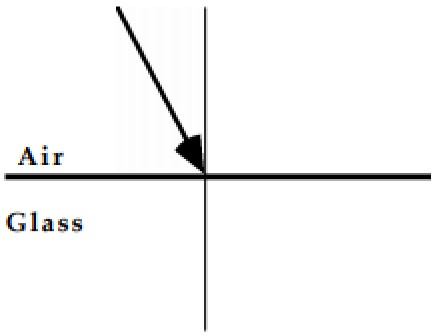
5) A laser beam is incident upon ethanol at an angle of 37°. What is the angle refraction?

6) Light starting in air is incident upon a piece of crown glass at an angle of 45°. What is the angle of refraction?

7) An incident ray in air is approaching the boundary with glass at an angle of incidence of 35.5^0 . Calculate the angle of refraction. Draw the refracted ray on the diagram.



<u>Lesson 6 (control group)</u>

Topic:

Application of Snell's Law in Daily Life Situations.

Time allotted for lesson:

50 minutes.

Short description of lesson:

Students will work independently to solve daily life situations problems using Snell's law.

Scientific content and concepts:

http://farside.ph.utexas.edu/teaching/302l/lectures/node128.html

Learning outcomes:

Students will be able to:

- Use Snell's law to solve a given exercise.
- Reflect on the importance and value of Snell's law.

Students' prerequisite knowledge and skills:

- State Snell's law.

Instructional Procedures:

Time	Activity
5 mins	Recap from last session; teacher will state Snell's law and provide an example of its uses in everyday life.
20 mins	Lesson VI- Handout (1) will be introduced. Students will work independently to complete and solve the worksheet using Snell's law. Teacher will pass by to check students' answers.
20 mins	Students will solve the exercises on the board with teacher's guidance and explanation. Students will be encouraged to ask clarification questions.
5 mins	Wrap up; students will be asked to reflect on the importance and value of Snell's law.

Student products:

Students will use Snell's law to solve given exercises.

Assessment of learning outcomes:

Lesson VI – Handout (1) will be used as a formative assessment.

Lesson VI – Snell-Descartes Law

Handout (1)

Application on Snell's Law

1) **Explain why a person's legs appear shorter than they really are when they are standing in the water.**

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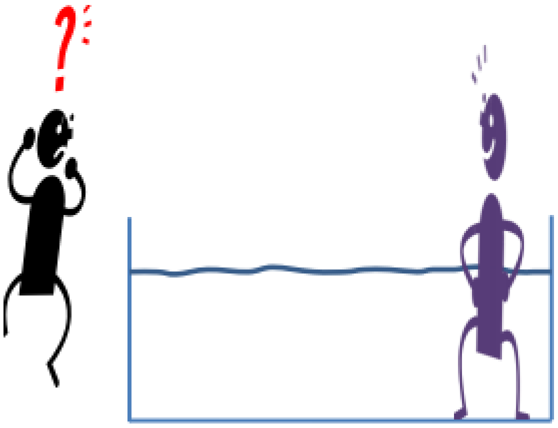

2) **Explain why when you are using goggles underwater, everything appears enlarged.**

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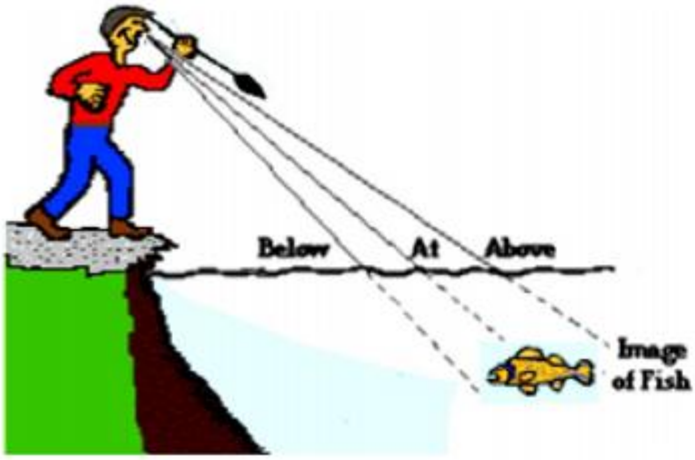
3) **Arthur Podd's method of fishing involves spearing the fish while standing on the shore. The apparent location of a fish is shown in the diagram below. Because of the refraction of light, the observed location of the fish is different than its actual location. If Arthur is to successfully spear the fish, must he aim at, below, or above where the fish appears to be? Explain.**



4) **A fish underwater sees a fisherman standing on the side of a lake. How does he appear? Smaller or bigger? Explain.**

Appendix D
Questions of Focus Group Discussions

List of FGDs Questions before the Intervention

1. How do you perceive science classes? (Fun/boring? easy/difficult? interesting/dull?)
2. How do you perceive physics classes?
3. What kind of physics class activities do you enjoy/love the most/find interesting?
4. What kind of physics class activities do you find boring/hard/enjoy the least?
5. What kinds of information/topics are useful/important to learn about in a physics class?
6. What kinds of information/topics are unimportant/of minor importance to learn about in a physics class?
7. How do you perceive science majors/ further science education?
8. Would you like to continue your education in the science field? Why/why not?
9. How do you perceive science careers?
10. Would you like to work in the science field? Why/why not?

List of FGDs Questions after the Intervention

1. How do you perceive the covered physics unit?
2. What kind of class activities did you enjoy/love the most/find interesting?
3. What kind of class activities did you find boring/hard/enjoyed the least?
4. What kinds of information did you find useful/important to learn about?
5. What kinds of information did you find unimportant/of minor importance to learn about?
6. Does this unit change your perception of science education?
7. Would you still like to continue/not continue your education in the science field? Why/why not?
8. Does this unit change your perception of science careers?
9. Would you still like to work/not work in the science field? Why/why not?
10. Does this unit change your perception of science?

Questions of Focus Group Discussions (Arabic)

List of FGDs Questions before the Intervention

1. **ما هي نظرتكم لصفوف العلوم؟ مسلية/مملة؟ سهلة/صعبة؟ مثيرة للاهتمام/غير مثيرة للاهتمام؟** *كيف بتشوفو صفوف العلوم؟ شو رأيكم فيهم؟ بتحسوهن بسلّو أو بزهقو؟ سهلين أو صعبين؟*
2. **ما هي نظرتكم لصف الفيزياء؟** *كيف بتشوفو صفوف الفيزياء وشو رأيكم فيها؟*
3. **ما هي النشاطات الصفية في مادة الفيزياء التي تعجبكم/تستمتعون بها/تثير اهتمامكم؟**
4. **ما هي النشاطات الصفية في مادة الفيزياء التي تعتبرونها مملة/صعبة/لا تستمعون بها؟**
5. **ما هي المعلومات/المواضيع التي ترغبون التعلم عنها وتجدونها مفيدة في مادة الفيزياء؟**
6. **ما هي المعلومات/المواضيع التي لا ترغبون التعلم عنها ولا تجدونها مفيدة في مادة الفيزياء؟**
7. **ما هي نظرتكم للاختصاصات العلمية الجامعية؟** *كيف بتشوفو الاختصاصات العلمية وشو رأيكم فيها؟*
8. **هل ترغبون التخصص في اختصاصات علمية؟ لماذا/لم لا؟**
9. **ما هي نظرتكم للمجالات العملية؟** *كيف بتشوفو المجال العلمي وشو رأيكم بهالمجال؟*
10. **هل ترغبون العمل في المجال العلمي؟ لماذا/لم لا؟**

List of FGDs Questions after the Intervention

1. **ما هي نظرتكم لدروس الفيزياء التي تعلمتم عنها في الست حصص الماضية؟** *كيف شفتو الدروس؟*
2. **ما هي النشاطات الصفية التي اعجبتكم/استمتعتم بها/اثارت اهتمامكم؟**
3. **ما هي النشاطات الصفية التي اعتبروتموها مملة/صعبة/لم تستمعوا بها؟**
4. **ما هي المعلومات/المواضيع التي وجدتموها مفيدة ومهمة ؟**
5. **ما هي المعلومات/المواضيع التي وجدوتموها غير مفيدة ولا ضرورة للتعلم عنها؟**
6. **هل تغيرت نظرتكم للاختصاصات العلمية الجامعية؟** *غيّرتو رأيكم بالاختصاصات العلمية؟*
7. **هل لا زلتم ترغبون التخصص في اختصاصات علمية؟ لماذا/لم لا؟**
8. **هل تغيرت نظرتكم للمجالات العلمية العملية؟** *غيّرتو رأيكم بالمجالات العلمية وبالشغل بهالمجالات؟*
9. **هل لا زلتم ترغبون العمل في المجال العلمي؟ لماذا/لم لا؟**
10. **هل غيرت هذه الدروس نظرتكم للعلوم؟** *غيّرتو رأيكم بالعلوم بشكل عام؟*