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IMPACT OF ARGUMENTATION AND ENGLISH LANGUAGE PROFICIENCY ON LEBANESE STUDENTS' ARGUMENTATION SKILLS AND CONCEPTUAL UNDERSTANDING OF GENETICS

by
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AN ABSTRACT OF THESIS OF

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Title: Impact of Argumentation and English Language Proficiency on Lebanese Students' Argumentation Skills and Conceptual Understanding of Genetics

Scientists have long used argumentation to make a case for their claims about the natural world. Researchers claim that the lack of incorporation of argumentation in science education contributes to the misrepresentation of science and to students having no sense of how scientific ideas came to be. They also claim that the incorporation of argumentation in science classes yields larger gains in conceptual understanding of a scientific topic than do traditional teaching methods (Osborne, 2010).

According to Dawson and Venville (2013), the interaction between argumentation and conceptual understanding is vague and requires further investigation. Sadler and Fowler (2006) claim that argumentation is effective for college students only. A study conducted by Torres and Zeidler (2002) has also shown that English language proficiency is a critical aspect which affects students' acquisition of science content knowledge. Thus, the purpose of this study was to further investigate the interaction between argumentation and conceptual understanding in a scientific context. The study also examined the effect of English language proficiency on Lebanese students' acquisition of argumentation skills, specifically because English is the language of instructions of science in Lebanon while the mother tongue is Arabic. Hence, the study investigated the following questions: (a) does explicit argumentation instruction impact secondary students' argumentation abilities; (b) does the English language proficiency of Lebanese secondary students impact their acquisition of argumentation skills?; (c) does explicit argumentation instruction in teaching genetics impact secondary students' conceptual understanding of genetics as compared with conventional instruction that covers the same content?

The research design of this study was quasi-experimental. Subjects in this study were 11th grade scientific section students in a K-12 co-educational private school. The experimental group received explicit argumentation instruction within the context of genetics, whereas the control group did not receive instruction on argumentation throughout the unit. However, to equalize instruction time between both groups, the control group students engaged in more discussions relevant to the content of the unit. All students involved in the study were categorized into three groups (high, middle, and low achievers) based on their average grades in English language. Students completed a survey about a genetics socio-scientific issue and a genetics content knowledge test before and after the unit. Data analysis occurred at three levels: analysis of participants' understanding of argumentation with its elements based on Toulmin's (1958) classification scheme of argumentation pattern, analysis of the effect of English language proficiency on argumentation skills, and analysis of participants' understanding of genetics. Findings of this study indicate that explicit argumentation instruction enhances high school students' argumentation skills and conceptual understanding of genetics. Results also indicate that explicit argumentation instruction has a differential effect on students based on their language capabilities, with high and intermediate language ability students benefiting more than low language ability students. The findings of this study may help educators to better plan their instructional approaches in high school science classes in order to enhance conceptual understanding and eventually academic achievement. Furthermore, findings of this study provide valuable insights about the effects of non-native language proficiency on high school students' argumentation skills and achievement.

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CHAPTER I

INTRODUCTION

Scientists have long used argumentation to make a case for their claims about the natural world. Whether it is new theories or evaluation of old data, argumentation is used by scientists to justify various views regarding a certain issue. It seems to be a critical feature to science practice and is essential in enhancing the construction of scientific knowledge. But, how is this related to science education? Researchers claim that the lack of incorporation of argumentation in science education contributes to the misrepresentation of science and to students having no sense of how scientific ideas came to be. Students are left with an impression that there exists a singular scientific method. Researchers also claim that the incorporation of argumentation in science classes yields larger gains in conceptual understanding of a scientific topic than do traditional teaching methods (Osborne, 2010).

According to Nussbaum and Sinatra (2003), an argument involves cognitive processes where an individual is required "to construct a rationale for a particular outcome, refute opposing viewpoints, and weigh competing considerations" (p. 385). According to Osborne (2010), argumentation is said to have the potential of involving students in classroom discussion and hence making their thoughts noticeable which might also assist in addressing misconceptions. Previous research has found that involving students in discussions of scientific issues and controversies increases their curiosity, task engagement, and intellectual reflection. Specifically, when students are asked to argue for another position they will have to think well about the alternative notions, compare and contrast their argument against various conceptions, explain the resulting information, and consider issues and arguments.

Research findings support the claim that argumentation is a promising tool in promoting knowledge restructuring in students. To start with, Zohar and Nemet (2002) investigated ninth grade students' gain in biological knowledge after argumentation instruction was explicitly taught and integrated within human genetics. The results of the study showed that when students were explicitly taught argumentation, the frequency of those who stated correct and specific biological knowledge increased. Also, students in the experimental group had higher scores than students in the comparison group on the genetics knowledge posttest. There was as well an increase in the quality of the experimental group students' argumentation skills and their ability to transfer the reasoning skills that they acquired in genetics to the context of issues taken from everyday life.

Kuan- Hue and Hsiao-Ching (2010) studied the effect of argumentation on students' conceptual knowledge of chemical reactions, conceptual change related to chemical reactions, and chemical reaction dependent argumentation. The study examined the effectiveness of an online science learning program on eighth grade students' argumentation abilities and conceptual change. Results showed that students in the experimental group had better performance than students in the control group; students' argumentation abilities and conceptual change were both enhanced through receiving the online science learning program. The researchers explained that the study further supported their claim that argumentation facilitates students' acquisition of correct notions of chemical reactions, encouraged conceptual change related to chemical reactions, and enhanced their argumentation abilities.

Nussbaum and Sinatra (2003) have also conducted a relevant study in which they claimed that participating in an argument promotes thinking and high engagement necessary for content learning when studying Newton's first law. The researchers studied the influence of the construction of an argument on undergraduates' reasoning and their choice of problem solutions and compared the performance of the experimental group with the control group whose members did not argue an alternate path. Results indicated that the intervention was an important step in promoting students' understanding of Newton's first law.

Torres and Zeidler (2002) examined the effects of English language proficiency and levels of scientific reasoning skills on the acquisition of science content knowledge by non-native English language grade ten students. A factorial design was used in order to investigate the effect of English language proficiency and scientific reasoning on scientific content knowledge. Results highlighted the critical impact of language proficiency on students' performance on a standardized science test. The findings of this study indicated that an enhanced level of English language proficiency assists students in learning science.

Purpose and Research Questions

Dawson and Venville (2013) explained that we still do not comprehend in great detail how argumentation in science classes contributes to learning and what characteristics of learning settings are the most effective in producing arguments among students. They recommended that further studies on argumentation might be helpful especially when reasoning about dilemmas is integrated into various science topics and over long periods of time. Torres and Zeidler (2002) also suggested that investigating the effect of English language proficiency on science content learning is relatively neglected. Thus, the purpose of this study was to further investigate the effect of incorporating explicit argumentation instruction on high school students' argumentation abilities and conceptual understanding during the teaching of genetics. The study also examined the effect of English language proficiency on Lebanese students' acquisition of argumentation skills. Specifically, the study answered the following research questions:

1- Does explicit argumentation instruction impact secondary students' argumentation abilities?
2- Does the English language proficiency of Lebanese secondary students impact their acquisition of argumentation skills?
3- Does explicit argumentation instruction in teaching genetics impact secondary students' conceptual understanding of genetics positively more than conventional instruction that covers the same content?

Rationale of the Research Problem

According to Dawson and Venville (2013), the interaction between argumentation and conceptual understanding appears vague and requires further investigation. Some studies (e.g., Asterhan & Shwarz, 2007; Aydendiz, Pabuccu, Cetin, & Kaya, 2012; Chen & She, 2012; Khishfe, 2014; Nussbaum & Sinatra, 2003; Zohar & Nemet, 2002) have shown a positive association between argumentation and conceptual understanding. For instance, a recent study conducted by Khishfe (2014) highlighted the advantages of incorporating an explicit argumentation approach on students' argumentation skills and comprehension of nature of science aspects (NOS) in the context of socio-scientific issues. Findings showed improvements in argumentation abilities and NOS understandings for seventh grade students who received an explicit argumentation instruction. The experimental group students were also capable of utilizing their argumentation acquired skills while explaining their NOS understandings by the end of the study.

Similarly, Asterhan and Schwarz (2007) studied the effects of argumentation on the comprehension of evolution theory by undergraduates. They found that argumentative practices in a classroom play a significant role in enhancing undergraduate students' understanding of subject matter. Students in the argumentative conditions performed better on the delayed posttest than control students. These researchers explained that students achieve higher when they are asked to propose reasoned arguments in support of and in contrast to one's own and another person's views. Zohar and Nemet (2002) also found that grade 9 students who were involved in an argumentative discussion repeatedly had improved conceptual knowledge of genetics with a subsequent improvement in argumentation skills.

In contrast, Sadler and Fowler (2006) have questioned the supposed link between argumentation and conceptual understanding of a scientific topic. In their mixed-methods study, these researchers investigated how students use their genetics content knowledge as they justify claims related to genetic engineering. The researchers conducted interviews with 45 participants who represent three distinct groups: High school students who had variable genetics knowledge, college non-science majors with little genetics knowledge, and college science majors with advanced genetics knowledge. The findings of the study showed that students must have an advanced content knowledge in order to have significant effects of argumentation and subsequent content learning. Moreover, they claimed that students must have a certain degree of understanding of the chosen scientific topic referred to as “threshold level of knowledge” in order for them to be involved effectively in argumentation. For this reason, they claimed that college students are capable of engaging in argumentation of scientific or socio-scientific issues more effectively than high school students. Furthermore, findings of a study conducted by Lin and Mintzes (2010) revealed that success in learning argumentation skills is affected by the student ability levels. High-ability students have been more successful than low-ability students in engaging in effective debate on socio-scientific issues.

Finally, a study conducted by Torres and Zeidler (2002) has also shown that English language proficiency is an important factor which affects students’ acquisition of science content knowledge. Findings of this study have indicated that proficiency in English language contributes to effective content learning. These researchers also suggested that investigating the effect of English language proficiency on science content learning is relatively neglected.

Research so far suggests that the potentially beneficial effects of argumentation on concept learning have not been yet subject to extensive investigation, and that there are contradictory views in regards to the interaction between argumentation and conceptual understanding. Research results also suggest that it is important to investigate the effect of English language proficiency on students’ acquisition of argumentation skills. In an attempt to address these issues, the purpose of this study was to investigate (a) whether an explicit argumentation instruction improves high school students’ argumentation abilities; (b) whether English language proficiency affects students’ acquisition of argumentation skills;

(c) and whether explicit argumentation instruction improves high school students' concept learning of genetics.

Genetics was selected as the context for classroom argumentation because topics within this field provide students with an opportunity to formulate arguments and counterarguments and justify them because of the controversial nature of some issues related to genetics such as genetically modified organisms. Research has also shown that conceptual understanding in genetics involves much more than simple memorization of facts that commonly occurs in high school life science classrooms. In other words, the field of genetics is complex and requires an integrated in-depth understanding. Hence, enhancing conceptual understanding in genetics is not an easy task, thus requiring further research (Dawson & Venville, 2013).

CHAPTER II

LITERATURE REVIEW

The literature review presented in this chapter displays the meaning of argumentation, provides a historical overview of the role of argumentation in science, presents the rationale behind incorporating argumentation in science education, and presents the impact of language proficiency on students' acquisition of argumentation skills. The review of literature summarizes relevant empirical studies that have explored each of the previously mentioned research questions. The findings of these studies have been thoroughly investigated to form a clear understanding of how explicit argumentation instruction impacts students' argumentation skills and conceptual knowledge. The findings also provide insight about the impact of English language proficiency on students' acquisition of argumentation skills.

Meaning of an Argument

To start with, it is important to elucidate what is meant by an "argument". According to Nussbaum and Sinatra (2003), an argument involves cognitive processes where an individual is required "to construct a rationale for a particular outcome, refute opposing viewpoints, and weigh competing considerations" (p. 385). Toulmin (1958) presented a model that describes the constituents of argumentation and the relationships among them. According to Toulmin, the main components of argumentation include: claims, evidence, warrants, and backings. A claim is a notion that a proposer believes has the status of a certain truth. Evidence consists of the data which seem to back up the proposed claim. Warrants are general standards that link claims with evidence. They might be rules or principles that are suggested to justify the links between the evidence and the claim. As for backings, these are statements that function as assurances and are meant to justify a certain warrant. Toulmin described scientific argumentation as a means of using evidence, warrants, and backings to persuade others of a certain claim. For instance, the claim that diversity of species is a product of random variation and selection by the environment was supported by Darwin's data on the variety of finches' beaks which were found in the Galapagos Islands. The warrant, in this case, was that each adaptation gave each species a competitive advantage that ensured their survival on a certain island. Another example is the claim that the heliocentric model of Copernicus was true. This claim relied on a set of data acquired from observations of Jupiter's moon which were presented by Galileo. However, these data could not by themselves justify the Copernican claim. They required a warrant for that justification. The warrant, in that case, was an observation that falsified a basic premise of the Ptolemaic system.

Toulmin also identified two other features that are involved in the case of complex arguments. These include qualifiers which are limits of the claim and rebuttals which specify the conditions when a claim is to be falsified. Arguments that contain rebuttals are considered to be the most complex. They necessitate the ability to relate, differentiate, and distinguish different lines of reasoning. In science, arguments may arise over proposed claims, evaluation of theories, methods of data collection, or even the interpretation of collected data. These arguments might be verbal or written and usually depend on supporting visualizations such as graphs or symbolic models.

According to Kuhn (1992), an argument is said to have both an individual and a social meaning. The individual meaning of an argument is characterized by a person's internal chain of thoughts and reasoning in regards to a certain issue. The social meaning of an argument is characterized by the social display of these personal thoughts through a debate between people. Social argumentation is considered effective in promoting the higher order thinking skills. It is also an important vehicle that allows the display of internal or individual argumentation.

Historical Overview of Argumentation in Science

According to Jimenez-Aleixandre, Bungallo Roriguez, and Duschl (2000), history has proven that argumentation is a hallmark of science and an essential component of a scientist's work. A scientist argues with oneself through frequent personal claims and with others through publications, conferences, laboratory meetings, and informal occasions. Over time, ideas that survive critical examination through arguments and discourse attain acceptance within the community. Argumentation seems to be core to science practice rather than a peripheral feature; the construction of reliable knowledge is impossible without argument and evaluation. For instance, both a theoretician who suggests a certain claim and an experimentalist who proposes a certain method for data collection expose their ideas to argumentation.

Typically arguments used in science have three generally recognized forms: analytical, dialectical, and rhetorical. Analytical arguments are embedded within the theory of logic and proceed inductively or deductively. Dialectical arguments occur during a dispute or conversation. They involve reasoning with premises that are not visibly correct. Rhetorical arguments are represented by discursive techniques that are used in persuading an audience such as Darwin's argument for the theory of evolution, and this form of argument usually requires a great deal of knowledge and persuasion.

According to Zhou, Xu, and Wu (2006), the role of argument in science is noticeable during scientific revolutions. Based on the history of science, a new claim can replace a previous one through scientific argumentation. According to Kuhn (1992), historical examples such as the dialogues between the caloric and kinetic views of heat, the particle and the wave views of light, and the argument between Bohr and Einstein regarding quantum mechanics reveal that argumentation is involved in the construction of scientific knowledge.

In an attempt to highlight the significance of argumentation in science, Zhou et al. (2006) have presented the case of Franck-Hertz experiment in atomic physics. Franck and Hertz have conducted studies on the ionization of atoms by electron impact in 1911. These studies actually led the researchers to win the Nobel Prize later in 1925. In their first published report, Franck and Hertz interpreted their typical experimental value of 4.9ev as the ionization voltage of mercury. In the meantime, Bohr considered that the experimental value suggested by Franck and Hertz signifies the excitation voltage of an atom while it travels between different energy states. He then published a paper criticizing the interpretations of Franck and Hertz and stated that their experiment verified his prediction regarding the stationary state of atoms. Franck and Hertz then published another paper refuting Bohr's explanation. In 1919, Franck and Hertz finally accepted Bohr's interpretation. They then won the Nobel Prize in 1925, because the experiment that they conducted was a direct verification of Bohr's hypothesis. These scientists have actually spent five years justifying their claims. In short, an argument has aroused over Bohr's claim. Franck and Hertz conducted an experiment to refute that claim. But, the evidence that these two scientists collected further justified Bohr's prediction. The argument between these two parties has eventually confirmed Bohr's quantized model of the atom.

Nersessian (1989) presented an example of a significant conceptual change in the history of science whereby argumentation played a critical role. The researcher illustrated the historical construction of the principle of inertia which is considered a major aspect of the transition from Greek and medieval assumptions to modern science; scientists had to undergo major conceptual restructuring which involved changes in the concepts of motion, vacuum, and space in addition to the construction of the concept of gravity as a type of force. Galileo played a significant role in this historical issue because he challenged the Aristotelian distinctions, and his challenge actually marked a significant step in the construction of the principle of inertia. Galileo constructed a new representation and utilized idealization techniques and analogical arguments in an attempt to convince others of his claim. He began by illustrating the views of his challengers, then exposed the difficulties in their claim, and finally led his opponents through the formulation of a new representation of the situation being discussed.

Charles Darwin's publication *On the Origin of Species (1859)* is another significant example that illustrates the critical role of argumentation in science. According to Erduran and Jimenez-Aleixandre (2007), this book is described by many as "one long argument" that embodies two aspects of argumentation. The first aspect involves the explanation of knowledge claims by clarifying similar lines of reasoning, theoretical ideas and empirical evidence. This aspect was conveyed in Darwin's claim of the theory of natural selection: Darwin brought further justification to the population theory through the collection of empirical data in a journey to Central and South America. He then represented the collected data in his bold claim. The second aspect of argumentation (Erduran & Jimenez-Aleixandre, 2007) presented in the book involves persuasion. This was an attempt to persuade scientists and the public that animals and plants had changed; the living things on Earth have descended from other species instead of being created all at the same time. At that time, Darwin knew that convincing his challengers would be quite difficult and that was the main reason behind the twenty years of delay of the publication of his book. When Darwin's book was finally published, it then created a great controversy and stirred the debate in regards to his claims.

Role of Argumentation in Science Teaching

From the discussion so far, we realize that argumentation plays an integral role in science. One might wonder, however, why argumentation deserves to be endorsed within science education? Erduran and Jimenez-Aleixandre (2007) presented a rationale for why science educators are encouraged to promote argumentation in science classes. The researchers explained that the incorporation of argumentation in science learning contexts draws from two frameworks. The first framework is within the field of science studies, and it highlights the critical role of discourse in the development of scientific knowledge. The second framework is based on the sociocultural perspective which stresses the role of social dialogue in learning and thinking. This framework signifies that higher order thinking originates from socially driven activities, particularly through the use of language as a mediator. These researchers, thus, argued that argumentation is a form of discourse that must be explicitly taught through effective instruction, task structuring, and modeling.

Erduran and Jimenez-Aleixandre stressed the importance of introducing argumentation in science learning, because of the following five interrelated possible benefits:

- Making cognitive reasoning public which supports higher order thinking.
- Developing communicative capabilities and particularly critical thinking.
- Talking and writing science which achieves scientific literacy.
- Supporting the enculturation into the practices of the scientific culture and the development of epistemic criteria for knowledge evaluation.
- Supporting the development of reasoning, specifically the choice of theories or certain positions based on rational criteria.

Erduran and Jimenez-Aleixandre explained that argumentation makes cognitive processes public. When students are encouraged to justify their thoughts based on evidence and to assess other choices, their higher order cognitive processes develop considerably. The researchers also explained that argumentation facilitates the development of critical thinking. When teachers create environments where students are involved in argumentative discussions about scientific and/or socio-scientific issues, then the development of critical thinking skills among students is enhanced. Students will be educated citizens who are critical thinkers capable of reflecting on and influencing social issues related to their lives.

Erduran and Jimenez-Aleixandre (2007) also explained that critical reading and argumentation enhance scientific literacy. Consequently, the use of argumentative tools in instruction supports the development of students' scientific reasoning skills which will enhance their achievement of scientific literacy. According to BouJaoude (2002), scientific literacy is a universal requirement of the 21st century if people do not wish to be isolated from their society and the rest of the interconnected world. A scientifically literate individual is capable of making personal decisions and engaging in the civic, cultural, and economic productivity of his/her country.

Erduran and Jimenez-Aleixandre (2007) further explained that argumentation potentially fosters the development of epistemological understanding among students. An understanding of scientific epistemology allows students to justify and evaluate scientific knowledge. They also highlighted that it is important to promote the development of epistemic criteria, because this will enhance the effective participation of students in policy decisions and the interpretation of scientific statements related to their daily lives. Actually, the relationships between argumentation and epistemology are similar to the notions of critical thinking and scientific literacy discussed earlier. As for the development of reasoning skills and rational criteria, Erduran and Jimenez-Aleixandre explained that the ability to pick among theories and positions is part of the epistemological development. In other words, epistemic criteria are rational characteristics that can be enhanced through argumentation. In summary, argumentation holds the potential to help students further comprehend and assist the learning processes in science classes.

Posner, Strike, Hewson, and Gertzog (1982) have as well justified in their study why teachers and science educators are encouraged to endorse argumentation in science classes. They explained that students usually have their personal understandings of the world that might be in many cases different from scientific concepts. These different conceptions set an opportunity for arguments to evolve in the science classes. Posner et al. were interested in exploring the process of conceptual change during which students' organizing concepts change and interact with new incompatible ideas. They were driven by the question of how students' conceptions are affected by new evidence. According to them, learning is a process of conceptual change which consists of two phases. The first phase is referred to as assimilation. During this phase, students utilize their personal conceptions in order to deal with the phenomenon at hand. This phase is similar to the research programs that scientists generate and use in order to apply to or defend their central commitments. The second phase of conceptual change is referred to as accommodation. This occurs when students' current concepts are inadequate and must be reorganized or replaced by new central concepts. This kind of conceptual change is analogous to the notion of scientific revolutions. The researchers claimed that scientists and students are unlikely to modify their personal conceptions unless they get dissatisfied with these existing conceptions. A new conception on the other hand must appear plausible, intelligible, and provides room for inquiry.

Posner et al.'s study shows that anomalies and fundamental assumptions are considered as two important features in science. Anomalies provide students with a cognitive conflict which most likely results in accommodation. Metaphysical beliefs and epistemological commitments help students in making judgments about new conceptions. Conceptual change is then the result of a rational process in which students have the required standards of the judgment necessary for a certain change. Sinatra and Pintrich (2003) further explained that the students' intentions affect their process of knowledge restructuring and conceptual change. According to these researchers, conceptual change is an intentional goal-directed action characterized by the students' control of their cognitive, metacognitive, and motivational factors in an attempt to bring about a change in their knowledge. These researchers have suggested that instructional strategies must be designed with an aim to promote intentional conceptual change. They explored innovative views of conceptual change learning by bringing together distinguished contributions of scholars in a variety of disciplines. Argumentation is an innovative possible strategy where educators can support students in accommodating new conceptions on a rational basis. Students' preconceptions and opposing viewpoints in many scientific issues assist in the development of arguments in science classes. An argumentation approach hence encourages students to share and listen to opposing viewpoints. Such a strategy can then promote intentional conceptual change, because it allows the instructor to assist students in two important processes: breaking down less acceptable ideas and establishing acceptable scientific ideas instead. This process is dynamic, dialectical, and is driven by the argument held in class. In conclusion, argumentation might help students further discover the inconsistencies in their previous ideas and better understand the concept at hand.

It is important to clarify as well that argumentation in science classes is unlike the traditional views of science learning that emphasize only the results such as problem-solving or science process skills. During this type of teaching, teachers may tend to offer many explanations, but these are not arguments. Typically, classroom discourse in science classes evolves into a monologue. This is demonstrated as a unidirectional discussion where the students do not engage in questioning probably because they do not have enough resources in order to challenge the teacher's affirmations. The world then appears to the students as a set of principles, represented by "correct" and "false" answers, with the warrants and data for their beliefs and any other element of uncertainty eliminated (Osborne, Erduran, Simon, & Monk, 2001).

In summary, this section has highlighted the critical role of argumentation in science education. It is important to state as well that argumentation is still rarely incorporated in science classes even though it is central to science education (Driver, Newton, & Osborne, 2000).

Argumentation and Conceptual Understanding of Science Topics

The discussion so far draws from the literature the importance of incorporating argumentation in science classes, because it potentially helps students better comprehend science and can support the learning processes in science classes. The potential contributions of argumentation have led many researchers to the assumption that argumentation can enhance concept learning due to the fact that this instructional tool interlinks several social and cognitive processes which are in turn considered to enhance conceptual understanding (Asterhan & Shwarz, 2007). According to Driver et al. (2000), dialogic argument enhances conceptual understanding because it provides students with a chance to socially develop their self-knowledge. This section hence presents empirical studies that were conducted with students of various educational levels. These studies have investigated the effect of argumentation on students' conceptual understanding of major scientific ideas and processes.

Argumentation in College

Ayendiz, Pabuccu, Cetin, and Kaya (2012) investigated in an experimental study the impact of explicit argumentation instruction on college students' understanding of the properties and behaviors of gases. The sample consisted of 108 students of which 52 were in the control group and 56 in the experimental. Students were chosen from two general chemistry college courses which were taught by the same instructor and had to sit for pre and posttests. The findings of the study revealed that those in the experimental group achieved better than those in the control group on the posttest. The experimental group students also performed better on the posttest than on the pre-test. At the beginning of the study, the researchers identified 17 alternative conceptions held by all students. The results of the study as well indicated that approximately 80% of the students in the experimental group abandoned these preliminary ideas on all of the 17 alternative notions but one, whereas less than 50% of the control group students abandoned these alternative notions.

Asterhan and Shwarz (2007) investigated the effects of argumentation instruction on the conceptual understanding of evolution. The investigators conducted two experiments. In the first experiment, 76 undergraduates were randomly allocated to an experimental and a control group. All participants were asked to collaboratively answer questions on evolution. The experimental group students were also asked to conduct an argumentative discussion (dialogical argumentation), while control group students were only asked to solve the items collaboratively. The second experiment consisted of 42 undergraduates which were also randomly allocated to an experimental and a control group. Experimental group students were asked to engage in a monological argumentation in response to their answer and their partner's answer after prompts were read by the partner. Whereas, students in the control group were asked to simply share their solutions. The investigators assessed students' conceptual gains by administering instantaneous and postponed posttests. Findings of both experiments showed that experimental group students had greater learning gains on the postponed posttest than students in the control groups. Also, students in the experimental groups were capable of preserving immediate gains following the experiment. On the other hand, control group students lost their immediate gains (1st experiment control group) or did not develop their conceptual understanding at any time (2nd experiment control group).

Nussbaum and Sinatra (2003) have claimed that participating in an argument will promote the deep processing and high engagement necessary for conceptual change learning. Their study explored the possibility for argumentation in science education to enhance conceptual involvement and eventually conceptual change. These researchers have chosen a physics problem in order to investigate undergraduate students' understanding of Newton's first law which states that an object in motion remains in motion unless it is acted on by a force. Participants involved in the study consisted of 41 undergraduates (35 females and 6 males) who were registered in an educational psychology course and had to participate in the study in order to meet their course requirements. The participants that were selected did not have a strong knowledge in physics. They were asked to guess the path of a falling object dropped in three different situations. Participants were then randomly assigned into a control group that received a control treatment and an experimental group that received an experimental intervention on an individual basis. Control group members were only asked to solve the questions and had to explain their answers orally and in writing. They were then shown the correct solutions through a computer simulation program. Participants of the experimental group who gave a correct answer were asked to perform the same requirements as those requested from the control group. But, the experimental group members who answered incorrectly were asked to construct an argument for an alternative (without being told that it was the correct choice) and were then asked to reevaluate their answers.

The researchers then studied the impact of the construction of an argument on the quality of participants' thinking processes and their choice of problem solutions; they compared the performance of the experimental group with the control group whose members did not argue an alternative path. These researchers anticipated that the experimental group members would make more accurate predictions and that their reasoning would more likely reveal consideration to basic aspects of the problem at hand. Results have actually indicated that the intervention was an important step in promoting students' comprehension of Newton's first law. The researchers claimed that argumentation is a promising tool in promoting knowledge restructuring in students and might be a useful educational technique. However, they recommended that further research regarding this issue be conducted.

Argumentation in High School

Sadler and Fowler (2006) also conducted a mixed-methods study in which they investigated the interrelationship between argumentation and conceptual understanding of genetics. The researchers conducted interviews with 45 members who represent three distinct groups: High school students who had variable genetics knowledge, college non-science majors with little genetics knowledge, and college science majors with advanced genetics knowledge. During these interviews, students stated their positions regarding three scenarios related to gene therapy and cloning. Students' arguments were then evaluated in regards to the number and quality of justifications offered using a rubric. Findings of this study showed that college students enrolled in science majors performed better than the other participants in regards to the quality and frequency of their stated justifications. Also, findings showed that college students enrolled in non-science majors and high school students did not exhibit different argumentation qualities. Based on the results, Sadler and Fowler suggested that students have a "threshold level of knowledge" in order to engage in meaningful argumentation and gain subsequent content knowledge. Hence, according to these researchers, argumentation instruction is more effective in college rather than high school because college students tend to have a more enhanced and well-organized body of knowledge than high school students.

Zohar and Nemet (2002) analyzed the learning outcomes when explicit argumentation instruction is integrated within the human genetics unit in grade nine biology classes. Ninth grade students were allocated to two groups: experimental (*N*=99) and comparison (*N*=87). All students were already exposed to basic genetics concepts before this study took place. They then studied further advanced concepts during the unit. Experimental group students learned these concepts through a specially designed 12-hour unit called "Genetic Revolution Unit" which consisted of activities that enhance higher-order thinking skills and scientific argumentation. The unit aimed to accomplish two goals: learning topics within human genetics and fostering argumentation skills. Students in the comparison group, on the other hand, learned the same concepts by a conventional method which consists of the traditional textbook approach. Students of both groups studied these concepts for an equal amount of time (approximately 12 lessons). Students were then assessed before, during, and after instruction through audiotaped discussions and written worksheets. Assessment before instruction showed that 16.2% of the students utilized accurate and specific biological knowledge in formulating arguments within the field of human genetics. Almost 90% of the students were capable of constructing simplified arguments. Evaluation that occurred post instruction showed that the utilization of an explicit argumentation instruction within the unit of human genetics develops students' performance in both content knowledge and argumentation abilities. Students in the experimental group had higher scores than students in the control group in the content knowledge test, and they showed an improvement in their argumentation abilities. These students were also capable of transferring their reasoning abilities to the context of other dilemmas from everyday life.

Argumentation in Middle School

Chen and She (2012) also conducted an experimental study to test the effect of frequent on-line synchronous argumentation learning on the development of students' scientific argumentation abilities and conceptual understanding in physical science. The study included 150 participants of grade 8 students. The control group which consisted of 76 students received traditional instruction while the experimental group which included 74 students received an on-line scientific argumentation program for 25 physical science class periods of 45 minutes duration each. The results showed that students in the experimental group performed better than the students in the control group on the post-physical science conception test and the argumentation test. Also, students in the experimental group were capable of constructing further accurate notions from pre- to post-argumentation questions across the seven topics of the study.

von Aufschnaiter, Erduran, Osborne, and Simon (2008) also investigated the link between content knowledge and argumentation in grade eight science classes. Research was done during a two year period: In the first year, material needed for argumentation instruction was constructed. During that year as well, 12 teachers were trained on enhancing effective argumentation in science classes. In the second year, a group of 6 teachers who showed progress in their ability in promoting argumentation were chosen to repeat their teaching on argumentation. These teachers integrated a series of nine-argument based lessons in grade 8 science classes over the course of one year. The first and the final lesson focused on a socio-scientific issue, and the lessons in between had a physics focus. The socio-scientific lessons were video and audio-taped in an attempt to assess the effectiveness of the teachers' argumentation instructional strategies and their progress within that field. Also, two groups of students, in each class, were video and audiotaped. The documents were then analyzed in order to determine the quality and frequency of students' argumentation. Hence, the data sources included the verbal conversations and the participants' activities that were audio and video recorded in the classes. The microanalysis of student discourse revealed that students refer to their previous experience and knowledge when engaging in argumentation. Argumentation allows students to associate their prior knowledge and promote their comprehension of science content at somewhat high degrees of abstraction. A major implication of this study is the need to consider students' prior knowledge before involving them in argumentation. Any attempt to improve students' conceptual knowledge through argumentation is thus significantly related to their prior knowledge and content-specific experiences.

Another study conducted by Kuan-Hue and Hsiao-Ching (2010) compared an online scientific learning program without argumentation to a program with an argumentation component. The study examined the difference in effectiveness of these programs on students' scientific argumentation abilities and conceptual change. The experimental group consisted of two classes of eighth grade students who participated in an online scientific argumentation learning program about chemical reactions for two weeks. The control group also consisted of two classes of eighth grade students but who participated in the same online scientific learning program deprived of argumentation. The participants had to sit for a scientific conception test, conceptual change test, and argumentation test before, one week after, and eight weeks after learning. The experimental group students' online argumentation process was also assessed. Results demonstrated that the experimental group students performed better than the control group students on the chemical reaction achievement test, chemical reaction conceptual change test, and chemical reaction dependent argumentation test. Students of the experimental group were capable of changing their conceptions across topics involving chemical reaction. The quantity and quality of their scientific arguments have also improved. In summary, these researchers have explained that the study further supported their claim that online argumentation facilitates students' conceptions of chemical reaction, conceptual change related to chemical reaction, and chemical reaction dependent argumentation.

The previously mentioned research studies demonstrate that argumentation in a science context can foster content learning. These studies were designed with a series of activities that allow students to actively generate arguments, face dissonance, interchange opinions, and eventually change their alternative conceptions. The results of these studies demonstrate that explicit argumentation instruction positively impacts students' conceptual knowledge and argumentation skills. However, as mentioned earlier, the assumed link between argumentation and conceptual understanding of a scientific topic has been questioned. It has been reported that the quality of argumentation generated by students can be affected by individual differences such as cognitive ability, prior knowledge, and language proficiency (Lin & Mintzes, 2010; von Aufschnaiter et al., 2008; Sadler & Fowler, 2006; Torres & Zeidler, 2002).

Argumentation in Elementary School

In a mixed-methods case study completed by Lin and Mintzes (2010), an experienced elementary school science teacher developed and utilized instructional resources for enhancing students' argumentation skills through socio-scientific issues and investigated dissimilarities in the argumentation skills of Taiwanese grade 6 students. The study was conducted on two classes of 34 students having various abilities and achievement patterns. In an attempt to investigate the impact of the students' ability and achievement levels on the qualities of their arguments, the researchers allocated the students into three categories based on their achievement (high, middle, and low achievers). Students were placed in these categories based on their average grades in mathematics, language, natural science, and social studies courses on two midterm exams and one final exam in the preceding semester. The teacher implemented a 17-hour unit that focused on a socio-scientific issue in which the students learned to construct claims and warrants, develop counterarguments, and provide evidence. Data included student responses to questionnaires and semi-structured interviews. A multiple regression analysis showed that the students' acquisition of argumentation skills is significantly linked to their cognitive ability levels. High achievers were capable of constructing complete arguments better than low achievers. High achievers were also capable of learning more about both the socio-scientific issue and how to generate applicable arguments. Alternatively, the low achievers lagged behind in their ability to construct effective arguments, counterarguments, and rebuttals which might be probably related to their limited content knowledge. Results of this study demonstrate that individual differences in acquiring argumentation skills and content knowledge must be taken into consideration.

The previously mentioned research studies reveal that there are conflicting views in regards to the interaction between argumentation and conceptual understanding. Some studies (e.g., Asterhan & Shwarz, 2007; Aydendiz, Pabuccu, Cetin, & Kaya, 2012; Chen & She, 2012; Khishfe, 2014; Nussbaum & Sinatra, 2003; Zohar & Nemet, 2002) have shown a positive relationship between argumentation and conceptual understanding, whereas, other studies (e.g., Lin & Mintzes, 2010; von Aufschnaiter et al., 2008; Sadler & Fowler, 2006; Torres & Zeidler, 2002) have questioned the assumed link between argumentation and conceptual understanding of a scientific topic. The findings of these studies signify the importance of taking into consideration individual differences such as ability level, prerequisite knowledge, language proficiency, and/or social environment while investigating the effectiveness of argumentation instruction in science education.

It is true that there are many studies on argumentation in science education. However, most of the studies in the literature do not explore the impact of individual differences on students' argumentation abilities. Dawson and Venville (2013) have explained that it is important to investigate the effect of an explicit argumentation instruction on students' conceptual knowledge and argumentation skills in various science topics and over long periods of time. Lin and Mintzes (2010) stressed as well that it is important to investigate the effect of students' individual differences such as their social environment, prior knowledge, and/or language proficiency on the quality of arguments generated. The following section hence presents empirical studies that have explored the impact of language proficiency on students' argumentation skills.

Language Proficiency and Argumentation Skills

Lin and Mintzes (2010) explained that argumentation is not just a form of discourse but also a language-driven instructional strategy. In an argumentation activity, students utilize their language in order to express their thoughts, whether orally or in writing. According to Cummins (1981), language proficiency consists of the basic interpersonal communicative skills (BICS) and the cognitive academic language proficiency (CALP). The BICS includes the natural informal conversations. For instance, students use their BICS when talking about everyday life events and concrete situations. CALP, on the other hand, is the type of language proficiency needed to read textbooks, to participate in argumentation, and to answer exam questions. Cummins claimed that students who do not have an advanced CALP lag behind in comprehending science and other academic topics. Hence, it is crucial to investigate cognitive academic language proficiency as an individual difference in students when they construct an argument and to take this individual difference into consideration when developing any instructional activity or resource.

Swanson, Bianchini, and Lee (2014) conducted a case study with high school science students in an attempt to investigate how students whose first language is not English participate in discourse-intensive science practices. Swanson et al. also identified ways in which teachers can effectively assist their students in developing and constructing arguments in science classes. This study extended research on discourse in science classes to involve the high school level since the expectations for arguments at this level are more sophisticated than in elementary or middle school. Fifty-four students (20 females and 34 males) involved in this study were Latino (87%), European American (6%), and African American (4%). Approximately 33% of the students spoke Spanish as the primary language rather than English. All of the students involved in the study were registered in a 20-week Integrated Coordinated Science (ICS) course. This course was basically an introductory high school science course. It consisted of four units that lasted for five weeks each and included topics in earth science, physics, chemistry, and biology. The textbook and guide of the ICS course consider argumentation and communication as fundamental to science education. The physics and chemistry units of the ICS course were chosen for this study. The two selected lessons within these units were sound waves from physics and atomic structure from chemistry. Students were videotaped during class instruction of both the sound waves lessons and atomic structure lessons. The researchers took field notes of classroom setting, discussions between the students, and group dynamics. They also conducted five semi-structured interviews with the teacher in which she provided data about her training and experience. The teacher also described her opinion of the significance of argumentation and communication in science classes and how she attempted to meet the requirements of students whose primary language is not English. The researchers collected as well a variety of student work which included quizzes, notebooks, and posters. The qualitative analyses of teacher interviews, class communication, and student documents showed that the teacher regularly utilized primary language support, thoughtful scaffolds, and small group instruction in order to help the students argue properly and covey their information. Results also indicated that students whose first language is not English experience challenges while reading and constructing oral or written arguments. Results of this study in general emphasize the critical role of language in learning science.

Torres and Zeidler (2002) investigated the effect of English language proficiency and scientific reasoning skills on the conceptual understanding of grade 10 Hispanic English language students. The study was performed on 158 grade 10 students who were enrolled in earth science, biology, and chemistry classes. Students involved in the study were Hispanic English language students and native English language speaking students. Language assessment and scientific reasoning skills tests were administered in order to place the students in categories based on the following characteristics: English language proficiency, scientific reasoning skills and native language (Hispanic English language students or native English language speaking students). The English language proficiency categories consisted of three levels (low, intermediate, or high). Students were placed in a specific category based on their scores in the TOEFL (Test of English as a Foreign Language) test. The scientific reasoning categories were intuitive, transitional, or reflective. Students were placed in either one of these categories based on a classroom test of scientific reasoning skills. The study took place over a period of approximately 12 weeks. A factorial design was utilized in order to investigate the impact of the three independent variables (English language proficiency, scientific reasoning, and language category) on the dependent variable (scientific content knowledge). The scientific content knowledge was a scale variable which reflected the results of grade 10 students on a standardized science test. ANOVA was used to determine if there was a three-way interaction among the three independent variables on students' achievement. Findings indicate that English language proficiency affects significantly students' achievement in science. Findings also show a significant 2-way interaction between English language proficiency and reasoning skill levels in relation to students' performance on standardized science tests. This finding indicates, in other words, that advanced English language proficiency and scientific reasoning skills promote students' capabilities in learning scientific topics. Results of this study further support the claim that English language proficiency is a critical individual difference that must be taken into consideration when designing effective school science curricula.

According to Curtis and Millar (1988), there is also a close connection between language proficiency and science concept learning. These researchers claimed that effective comprehension of abstract scientific concepts depends on the student's capability to utilize language to unravel his/her prior knowledge, and it also depends on the student's richness of ideas relevant to the scientific concept at hand. The study was conducted with 500 students aged 13 and above in two schools in England with approximately 25% Asian language speaking students. All students in the study (Asian and English) were learning science in English. Students were asked to write freely about a certain concept as much possible in order to expose their knowledge of the concept at hand. The concepts chosen for the free writing task included the following: temperature, weight, speed, electric current, power, and pressure. Each student was asked to write for about 30 minutes about three of the six previously mentioned topics. Students were also requested to state the language they use with their friends and families. Furthermore, they were asked to state how long they have been at school in England. Quantitative comparisons within and between groups of the Asian and English students showed that differences in free writing could be attributed to the student's general ease in and familiarity with the language of instruction rather than to factors specifically related to science. Findings of this study provide evidence on the importance of language in science learning. Curtis and Millar (1988) suggested that science teachers must realize the critical role of language in science classes and are advised to explicitly help students in overcoming their language difficulties.

In conclusion, the previously mentioned empirical studies are pertinent to this research study. However, as mentioned earlier, research on argumentation is still in its early stages; the potential beneficial effects of argumentation on concept learning require further investigation. It is important to further investigate the interaction between argumentation and conceptual understanding in various science topics. It is also important to examine the effect of English language proficiency on Lebanese students' acquisition of argumentation skills. In other words, a need for further extensive examination in regards to this issue called for my study.

CHAPTER III

METHODOLOGY

Research Design

As indicated earlier, the purpose of this study was to further investigate the effect of incorporating explicit argumentation instruction on high school students' argumentation abilities and conceptual understanding during the teaching of genetics. The study also examined the effect of English language proficiency on Lebanese students' acquisition of argumentation skills. The research design was quasi-experimental. It was not possible to randomly assign students into experimental and control groups, because the school did its own assortment process whereby students of mixed abilities studied in the same classroom. Hence, the classes were randomly assigned to experimental and control groups in order to improve the validity of the study.

Participants

Subjects in this study were 11^{th} grade (scientific section) students in a K-12 co-educational private school located in the city of Beirut. The school serves the members of the surrounding community in particular, and the nation in general, to whichever social status they belong and without discrimination. It aims to build the personality of an active member of the society who is qualified for admission to a university. The school was selected on the basis of accessibility and convenience. The school implements the Lebanese national curriculum and uses the National textbooks. It uses English as the language of instruction in science. As mentioned earlier, the study involved grade 11 scientific section students who were randomly divided into sections based on achievement as part of the school's policy. These sections were randomly assigned to the experimental and control groups. The study took place during the Life Science sessions. The students took two sessions of Life Science per week. The following table presents information about the experimental and control classes that have participated in the study.

Table 1

Information about the Experimental and Control Classes

Experimental/Control Classes	Grade	Number of Students
Experimental	11 (scientific section)	19
Control	11 (scientific section)	19

One female teacher who has 8 years teaching experience taught both groups. The teacher is a graduate of science education. She usually tries to implement different teaching methods during her classes and is aware of argumentation instruction. Prior to the intervention period, the researcher introduced the teacher to effective argumentation instruction in a number of one-on-one sessions. In these sessions, the teacher was further acquainted with Toulmin's argumentation model and its various components. She read information describing argumentation and its constituents, and she watched video samples of argumentation instruction in science classes. The researcher explicitly explained this instructional strategy and reminded the teacher that she must try as much as possible to encourage debate, listen attentively, play the devil's advocate, and inspire reflection in order to promote effective argumentation. The researcher then supplied the teacher with the intervention period lesson plans for both the experimental and control groups. Both educators agreed to meet prior to each session in order to discuss and clarify the lesson plan components. These meetings also allowed the researcher to further follow-up and assess if there were any obstacles noticed during the intervention period. In addition, the researcher attended the lessons to ensure the authenticity of the treatment.

The students were informed that they were going to participate in an experimental study. However, they were not informed to which group they belonged (whether experimental or control). The researcher was also aware of the ethical responsibility towards the students and made sure that they would not get harmed in any way during the study as per the requirements of the university Institutional Research Board (IRB). The students' names were not published, and the instructional activities that were utilized in both groups did not cause any harm to any of the students; these activities were actually part of regular school practice. Moreover, at the end of the study, the instructional activities that were presented to the experimental group students were introduced to the control group students and vice versa because the researcher believed that all of the activities were of significance and could promote students' understanding of the topic at hand.

Intervention

Both groups were taught a 10 week unit on biological identity and genetic information that is a standard part of the grade 11 (scientific section) Lebanese life science curriculum. The unit covered topics on DNA, cell cycle, protein synthesis, biological identity, phenotype, genotype, genetic diseases, and genetic mutations. The control group students studied the content of the unit without receiving any explicit argumentation instruction; the teacher incorporated interactive instructional strategies while teaching the assigned unit topics but without any explicit argumentation instruction. As for the experimental group students, the teacher taught the same content but implemented explicit argumentation instruction during four sessions. The intervention on argumentation took place toward the end of the unit, because findings of previous studies indicated that students' argumentation skills could be enhanced if they had relevant pre-requisite content knowledge (Lewis & Leach, 2006).

Due to the packed Lebanese curriculum in grade 11 scientific section, teachers are always concerned about the limited amount of time they have to cover all the national curriculum content. This study thus allowed both groups to cover the same national curriculum content within the usual assigned duration but through the incorporation of different teaching strategies. So, the experimental and control group students received the same instruction in the first 7 weeks of the unit. The experimental group students then received explicit argumentation instruction during the 8^{th} and 9^{th} weeks unlike the control group students who were not involved in the intervention. The control group students were acquainted with the same topics but without the argumentation intervention. It is also important to clarify that spending four sessions on explicit argumentation instruction is significant enough. Kuhn (1991) explained that theoretically a short exposure to argumentation is effective enough and can result in significant changes in students' argumentation skills, because argumentation skills are usually latent and can develop significantly in a short period of time. Lewis and Leach (2006) also explained that secondary students can develop their content knowledge after a short duration of argumentation intervention.

Tables 2 and 3 present a general overview of the experimental group intervention and the instructional activities that were utilized while teaching the control group the same content within the assigned period. The intervention of this study is further described in detail in the next section. The lesson plans of all the sessions during the intervention period (for both groups) are also attached in Appendices A and B.

Table 2

Overview of the Experimental Group Intervention Period

Week	Duration	Activity	Activity Summary
8	20 minutes 30 minutes	What is argumentation? Toulmin Argumentation Model	Argumentation explicitly defined Students explored Toulmin's model
8	1 Session	Cystic Fibrosis Scenario	Students solved the worksheet and engaged in an argumentative discussion
9	1 Session	Gene Mutation Dilemma	Students solved the worksheet and engaged in an argumentative discussion
9	1 Session	Gene Cloning	Students solved the worksheet and engaged in an argumentative discussion

Table 3

Overview of the Control Group Instructional Activities

Week	Duration	Activity	Activity Summary
8	1 Session	Genetic Disorders	Students conducted a research on a specific genetic disorder and created a two pages medical sheet describing it
8	1 Session	Genetic Disorders	Students shared and discussed their findings about various genetic disorders
9	1 Session	Genetic Disorders Classwork	Students solved the worksheet on genetic disorders
9	1 Session	Gene Cloning	Gene cloning was explained and students solved a worksheet (classwork)

Explicit Argumentation Instruction

As mentioned earlier, the intervention consisted of 4 sessions (55 minutes each). In the first session, the experimental group students who were not previously exposed to any explicit argumentation instruction were introduced to argumentation. These students explored the meaning of argumentation and its various components based on the Toulmin (1958) model of argumentation. The teacher first implemented a short exercise that was developed by the Ideas, Evidence and Argument in Science (IDEAS) Project (Osborne, Erduran, & Simon, 2004b) as a brainstorming activity. In this exercise, the students reflected on their different perceptions of argumentation. They first solved the exercise individually and then discussed their answers with a partner identifying any points of agreement/disagreement before a whole classroom discussion was raised. During the classroom discussion, the teacher pinpointed the common perception based on the students' responses. She then defined argumentation and related it to the field of science. The teacher explained that the common beliefs (e.g. the earth is a sphere that revolves around the sun) which we now hold as true are a result of ideas that have been previously proposed by different scientists. In science, ideas are established by the interpretation of collected data from the real world. These scientific ideas are then subject to dispute and scrutiny. In general, arguments in science might arise over proposed ideas, evaluation of theories, methods of data collection, and interpretation of collected data (Osborne, 2010).

The teacher then explicitly introduced Toulmin's argumentation model through a short exercise similar to instructional activities conducted by Lazarou (2009). Toulmin's argumentation model was chosen to be introduced explicitly, because it is a good starting point for secondary students to be acquainted with the argumentation components. According to Khishfe (2014), Toulmin's model allows students to better understand arguments, develop their own, and argue against different perspectives. The students were asked to construct a concise well-written argument in an attempt to answer the following question: "Do you think that smoking in public places should be banned?" In their response, the students were asked to make sure to state their choice and support it with as many reasons as possible. The students first worked individually and constructed their own arguments. They then discussed their answers with a partner in order to evaluate the adequacy of each other's arguments before a whole classroom discussion was conducted. During the classroom discussion, the students shared their different points of view. The aim behind these discussions was for the students to actually realize that people's arguments might vary and someone's justification to a simple issue could be invalid at times. The teacher also guided the discussion in such a way that the various components of Toulmin's argumentation model got revealed. She then illustrated in a structured diagram (Figure 1) the discussed argument and filled in the various components of Toulmin's argumentation model so that the students familiarized themselves with the terms. The teacher also elaborated that Toulmin (1958) presented this argumentation model which allows people to argue effectively and evaluate each other's arguments; it is a well-structured model with clear components. The various argumentation components were defined, and the students received a handout (Appendix C) that contained information describing each component along with a diagram of Toulmin's model.

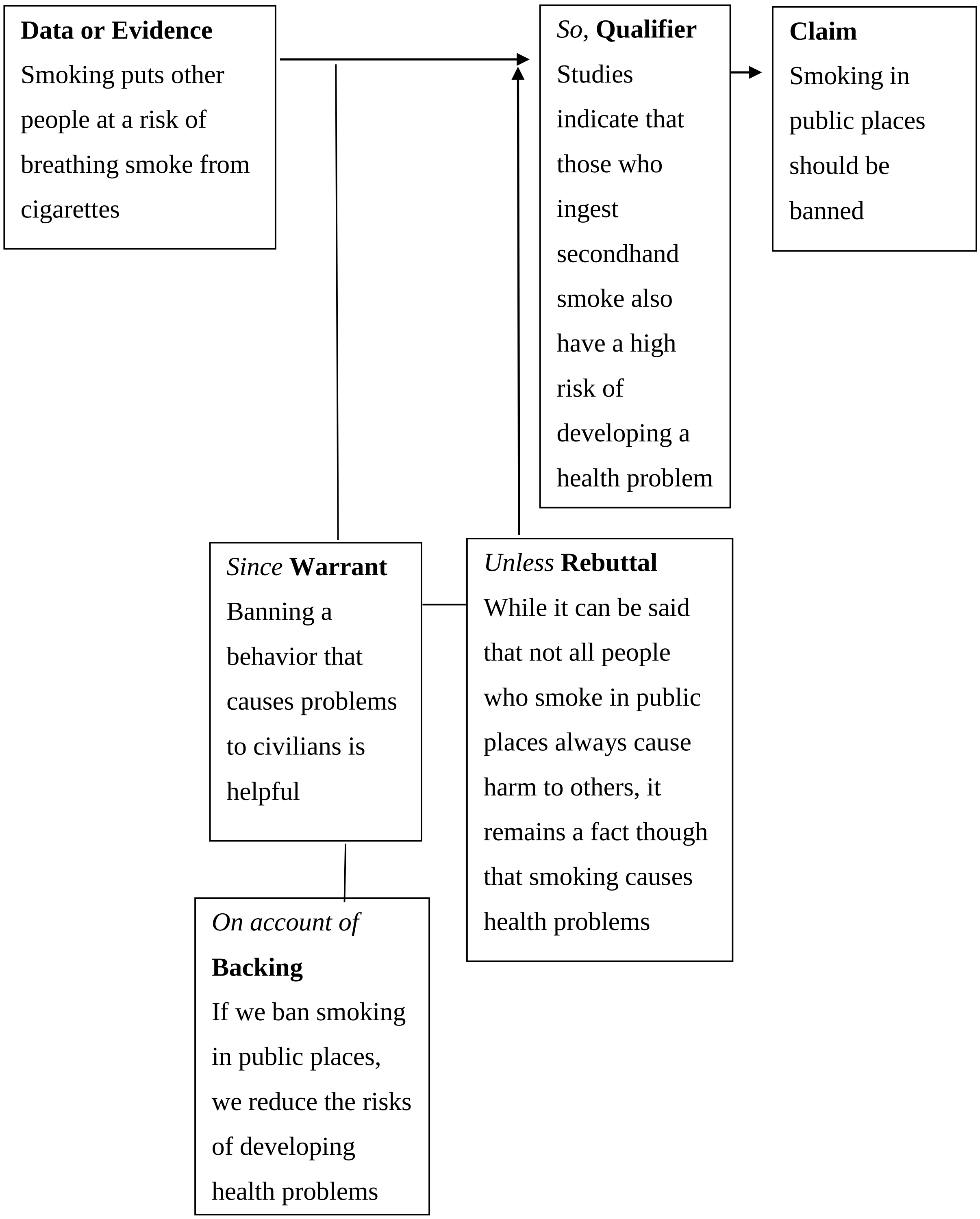

Figure 1. Components of argumentation. This figure illustrates a sample of a structured argument that developed during the classroom discussion.

Argumentation within Genetics Socio-scientific Issues

In the next three sessions, the students utilized their acquired argumentation skills in three classroom activities in which they were exposed to socio-scientific issues related to genetics. The genetics socio-scientific issues selected for the argumentation sessions dealt with a cystic fibrosis scenario, gene mutation dilemma, and gene cloning because they were related to the content of the unit and allowed both groups to cover the same concepts. Also, the students had the required pre-requisite content knowledge that allowed them to engage successfully in the argumentation activities.

In these argumentation sessions, the teacher used individual student writing frames and whole classroom discussion as teaching strategies. The writing frames consisted of questions that were specifically developed for each socio-scientific issue. These questions were mental prompts that assisted the students in formulating their arguments and expressing themselves individually. According to Dawson and Venville (2010), the utilization of writing frames in science classes can enhance students' thinking and writing skills. After the students formulated their arguments individually, they engaged in a whole classroom discussion. A whole classroom argumentation strategy was adopted during these sessions, because it allowed the students to express orally their views and be aware of other claims, data, rebuttals, warrants, and qualifiers that they probably did not consider on their own. The whole classroom discussion also allowed the teacher to have greater control over the ideas raised and discussed.

The students read the information written about the socio-scientific issue and answered the first two questions individually where they had to state their opinion regarding the issue and justify their decisions. The teacher then led a whole classroom discussion combined with periods when the students answered again individually the rest of the questions in the writing frames. In the remaining questions, the students stated and explained a possible counterclaim. They also explained how they would persuade someone with such a different opinion. During the whole classroom discussion, the teacher first read aloud the writing frames questions as a trigger for the argument. This helped the students further explore explicitly the various argumentation components in relation to the raised issue. The teacher encouraged all the students to share and articulate their thoughts. She restated the student views so that the entire class listened to the various responses. She also built on the students' answers by providing further evidence and requesting justification. The teacher also encouraged the students to respond to each other by acting as a facilitator. When students agreed on a claim, she tried to take a different position and stated a counter claim in order to assist the students in further expressing themselves.

Data Collection and Analysis

The following pages provide a description of the instruments that were used for data collection. These instruments included (student survey and genetics content knowledge test). This will be followed by the data analysis section.

Instruments

Before collecting any data, the English language proficiency of the students was determined by checking their overall average grades in the English subject matter. An average grade in English language was calculated based on all the oral and written assessments that were carried out in English classes. Based on the calculated overall average grades, the students were classified into an English language proficiency category (i.e. high, intermediate, or low). The data of this study were then collected through a student survey and a genetics content knowledge test. Table 4 presents an overview of the research questions, methods of data collection, and methods of data analysis.

Table 4

Overview of the Research Questions, Methods of Data Collection, and Methods of Data Analysis

Research Question	Method of Data Collection	Method of Data Analysis
1-Does explicit argumentation instruction impact secondary students' argumentation abilities?	Student Survey :The students were asked to state and argue their choice in relation to a genetics socio-scientific issue (attached in Appendix D)	- Pretest and posttest argumentation level based on Dawson and Venville (2010) categorization - Wilcoxon Signed Rank Test - Mann-Whitney U-test
2-Does the English language proficiency of Lebanese secondary students impact their acquisition of argumentation skills?	Student Survey :The students were asked to state and argue their choice in relation to a genetics socio-scientific issue (attached in Appendix D)	One-way ANOVA
3- Does explicit argumentation instruction in teaching genetics impact secondary students' conceptual understanding of genetics positively more than conventional instruction that covers the same content?	Genetics Content Knowledge Test (attached in Appendix D): The students were asked to answer 21 multiple choice items and 3 short answer questions	Genetic knowledge score (ANCOVA)

Student survey. All students involved in the study were assessed before and after instruction by completing a written survey. The survey was used in order to assess the students' argumentation skills within the field of genetics; the findings of the written survey provided answers to the first and second research questions. The same survey was given to the experimental and control groups prior to and after instruction. Prior to instruction, the survey was utilized in order to determine how students construct arguments when they do not have any pre-requisite argumentation knowledge. While after instruction, the same survey was utilized in order to examine the effect of the applied intervention on students' argumentation abilities (Cetin, 2014). The survey consisted of a genetics-based socio-scientific issue that was adopted from a study conducted by Dawson and Venville (2010). The students were given a short written scenario (designer baby dilemma) that is attached in Appendix D. They read the scenario and answered the following question: "Do you think such use of gene technology should be allowed?" The students constructed an argument in an attempt to support their point of view. In their response, they stated as many reasons as possible in order to clarify and justify their claim.

Genetics content knowledge test. In order to assess the students' understanding of genetics and answer the third research question of this study, a genetics content knowledge test was utilized. This test consisted of 21 multiple choice questions and three short answer questions that assessed the students' understanding of genetics and the relationship between genetics concepts. The test is attached in Appendix D. The multiple choice questions have been adopted from a genetic test that was previously constructed by Sadler (2004). Sadler developed a test referred to as the Test of Basic Genetics Concepts (TGBC). TGBC originally consisted of 23 multiple choice questions that cover nine major genetics concepts. This test allows educators to assess the students' basic understanding of genetics at the secondary school level. The nine major concepts that are targeted within the TGBC have been reviewed. Only one of these concepts was omitted because it is not addressed in the grade 11 scientific section class based on the Lebanese national curriculum. The remaining eight concepts were all aligned with the life science concepts that are addressed in the national curriculum of this class. Subsequently, two multiple choice questions were removed from the test. Hence, there was a total of 21 multiple choice questions that were used in this study. The genetics content knowledge test (multiple choice items and the three open-ended questions) was also checked by another researcher in order to make sure that the content of this test was aligned with the Lebanese national curriculum of this class beforehand.

As previously mentioned, the genetics content knowledge test also included three short answer questions that have been constructed and utilized in a previous study conducted by Dawson and Venville (2010). Dawson and Venville suggested in their study these three short answer questions, because they were concerned that the genetic multiple choice questions might not adequately assess students' conceptual understanding of genetics. The first short answer question required students to explain the meaning of the following terms: genome, gene, DNA, nucleus, chromosome, cell, amino acid, protein, and living. In the second short answer question, the students were required to explain the relationships between the nine given genetic terms. The third short answer question consisted of a genetic disease problem. The students had to read the problem and answer its questions. The three short answer questions were also checked before administering them by another researcher in order to make sure that they were aligned with the Lebanese national curriculum of grade 11 scientific section. The major concepts that were targeted within the genetics content knowledge test and that are aligned with the national curriculum of this class are presented within Table 5.

Table 5
Concepts Targeted in the Genetics Content Knowledge Test

Major Concepts	Description
Living things possess genetic material	A living organism contains genetic material within its cells. DNA is not present in non-living things.
DNA, genes, and chromosomes	Chromosomes are made up of thin filaments of DNA. Genes are specific regions of chromosomes that assist in controlling the expression of certain body traits. Human beings usually have the same number of chromosomes along with a similar gene sequence. Each individual possesses a unique DNA sequence, except in the cases of identical twins or clones.
Location of DNA	DNA is located inside the nuclei of cells. Every nucleated cell contains a full set of chromosomes (except for sex cells that are made up of half the number of chromosomes).
Chromosome number in body cells and sex cells	Body cells contain double the number of chromosomes found in sex cells such as sperm cells and egg cells. A karyotype of a body cell reveals the presence of pairs of chromosomes, whereas a karyotype of a sex cell indicates the presence of one chromosome of each pair.
Genes and protein synthesis	Genes are responsible for the synthesis of cellular proteins.
Dominance, Recessiveness, and Incomplete dominance	Alleles of a certain gene might be dominant, recessive, or incompletely dominant. A dominant allele is expressed in the phenotype when it is paired with a recessive allele. In the case of incomplete dominance, both alleles will be expressed in the phenotype.
Inheritance probabilities	Inheritance probabilities for traits controlled by a single gene with predetermined dominance patterns can be calculated.

Genetic diseases	Several human conditions can be caused or influenced by an individual’s genetic make-up. These genetic conditions may be the result of a single gene, multiple genes, or chromosomal abnormalities. Gene therapy has been proposed as a treatment for disorders caused by a single gene.

Data Analysis

Analysis of argumentation skills. According to Cetin (2014), the quality of students’ argumentation has been mostly investigated based on the Toulmin Argument Pattern (TAP). Dawson and Venville (2010) have modified this methodological approach in order to better assist researchers in analyzing the quality of students’ argumentation. In this study, the methodology that was developed by Dawson and Venville was utilized in order to assess the students’ argumentation skills. The unit of analysis consisted of the students’ written responses to the pre and post-instruction survey dilemma. The students’ written responses were categorized into Levels 0 to 4 based on whether they have included the argumentation components as defined by Toulmin (1958). Level 0 was assigned to students who did not respond. Level 1 was assigned to written responses that consisted of a claim only. Level 2 was assigned to written responses that consisted of a claim and a data/warrant used as an evidence in an attempt to support the claim. Level 3 was assigned to written responses that consisted of a claim, data/warrant, and backing or qualifier. Level 4 is the highest and most sophisticated level; This level was assigned to written responses that consisted of a claim, data/warrant, backing, and qualifier. Table 6 presents a summary of the argumentation categorizations.

Table 6

Argumentation Levels (Dawson & Venville, 2010, p. 961)

Levels	Description
Level 0	No claim or justification
Level 1	Claim only
Level 2	Claim, data (evidence supporting the claim) and/or warrant (a relationship between the claim and data)
Level 3	Claim, data/warrant, backing or qualifier
Level 4	Claim, data/warrant, backing and qualifier

All of the students' written responses were assessed by the researcher and another science education researcher using Dawson and Venville (2010) method of analysis. Both researchers first met and discussed Dawson and Venville framework. They coded a few samples of the students' written responses together as a practice. Afterwards, 15% of the responses were randomly selected and coded independently by each researcher. Both researchers then met in order to discuss the coding and an agreement rate was achieved between the coders. The inter-rater reliability is reported in the results. All of the students participating in this study were assigned to a pre-instruction and post-instruction argumentation level. The pre and post-instruction argumentation levels were entered into the Statistical Package for the Social Sciences (SPSS) database. The data generated do not meet the requirements for parametric analysis due to their ordinal nature. Hence, non-parametric analysis was used in order to answer research questions 1 and 2. The Wilcoxon Signed Rank Test (1st research question method of analysis) was used in order to determine if there were any significant differences between the pre- and post-instruction levels of argumentation for each group. The Mann-Whitney U-test (1st research question method of analysis) was also used in order to determine if there were any significant differences between the control group and experimental group's pre-instruction and then post-instruction patterns for the argumentation level dependent variable. In order to assess the effect of English language proficiency on students' argumentation skills (2nd research question method of analysis), one-way ANOVA was carried out using the pretest and posttest argumentation categorizations as the dependent variables.

Analysis of genetics content knowledge. Each of the 21 multiple choice questions was scored as zero for an incorrect answer and one for a correct answer (the answer key is attached in Appendix D). Hence, the total grade on the multiple choice questions was out of 21. In regards to the first short answer question, a student received a score of zero for an incorrect answer or no answer, one point for a simple answer, and two points for a complete answer. The researcher and another science education researcher scored independently each of the written responses based on an agreed upon answer key (attached in Appendix D) of the first two open-ended questions in order to ensure reliability. Both researchers then met in order to discuss if there were any scoring discrepancies until consensus was reached. An answer was considered as simple or complete based on the two researcher's interpretation of the understandings that were expected generally for grade 11 scientific section genetics. For instance, a simple answer definition of a gene could be "inherited traits carried through family" while a complete answer definition of a gene is a "DNA fragment that codes for the synthesis of a specific protein". The total grade on the first short answer question was thus out of 18 for the definitions of the nine genetics terms. In regards to the second short answer question, the students' responses demonstrated their understanding of the relationships between the nine given genetics terms. The students were requested to explain the relationships between: (a) living, cells, and genes; (b) genes, genome, and chromosome; and (c) DNA, protein, and amino acid. The students' responses indicated if they had a clear understanding of these three sets of relationships that could be formed from the nine given terms. Again in regards to this question as well, two researchers scored independently the students' written responses based on an agreed upon answer key (attached in Appendix D) in order to ensure reliability. The researchers also met afterwards in order to discuss if there were any scoring discrepancies until consensus was reached. The students received three points for each of the three sets of demonstrated relationships. If they demonstrated all three sets of relationships, they received a total of nine points. Hence, the total grade on the second question was out of 9. The third short answer question was related to a genetic disease. The students read the genetics problem and answered its questions. The total grade on the third question was out of 7 (check appendix D). The overall grade on the genetics content knowledge test was out of 55 (21 for the multiple choice part + 18 for the first question + 9 for the second question + 7 for the third question). Again, all of the students participating in this study received a genetics content knowledge pre-instruction and post-instruction score that was out of 55. These pre-instruction and post-instruction scores were then entered into the SPSS database. The researcher used ANCOVA in order to determine the interaction between the two independent variables of time (pre- and post-instruction) and argumentation (control and experimental groups).

CHAPTER IV

RESULTS

As previously mentioned, the data of this study were collected through a student survey and a genetics content knowledge test. These instruments were used before and after instruction. The survey was utilized in order to assess the students' argumentation skills within the field of genetics. The findings of the survey provided answers to the first and second research questions. The genetics content knowledge test was utilized in order to assess the students' understanding of genetics and provided findings in regards to the third research question. This chapter presents an overview of the results of this study.

First Research Question: Students' Argumentation Skills

The students filled out the argumentation survey before instruction and after instruction. The responses were categorized into Levels 0 to 4 based on whether the students included the argumentation components as defined by Toulmin (1958). All of the students were assigned to a pre-instruction and post-instruction argumentation level using Dawson and Venville (2010) method of analysis. To ensure the reliability of the categorization, a sample of the data (15 %) from the survey was analyzed by another science education researcher. The researcher and the science education researcher first met to discuss the categorization scheme. They then categorized the responses of a number of students together. Afterwards, a 15% sample was categorized independently by the researcher and the science education researcher. The inter-rater reliability was determined to be 85 %. A meeting was then held between the two and discrepancies were discussed in order to reach total agreement. The researcher then analyzed the rest of the data by herself.

The pre and post-instruction argumentation levels were then entered into SPSS database. Table 7 presents a description of the various argumentation levels and examples of student responses. As previously mentioned, non-parametric data analysis was used in order to answer the first and second research questions since the data generated do not meet the requirements for parametric analysis due to their ordinal nature.

Table 7

A Description of the Various Argumentation Levels and Examples of Student Responses

Levels	Description	Examples
Level 0	No claim	I do not know
Level 1	Claim only	I think such use of gene technology should be allowed
Level 2	Claim, data, and/or warrant	The use of gene technology should not be allowed since people should not interfere in God's creation. People should be satisfied with the qualities they have rather than faking what they don't have.
Level 3	Claim, data/warrant, backing or qualifier	The use of such gene technology should not be allowed, because this kind of procedure could be dangerous on the baby's health. It might result in unknown medical consequences. Another reason is that the baby might have traits different from those of his/her parents and would no longer seem to be their biological child.
Level 4	Claim, data/warrant, backing and qualifier	Such use of gene technology should be allowed. It ensures the presence or absence of particular genes that contribute to a healthy and disease-free newborn. Some might argue that an artificially selected genetic makeup is unethical or might contribute to a particular gender dominance. However, genetic therapy goes beyond physical traits to prevent the transmission of genetic diseases.

The Wilcoxon Signed Rank Test was performed in order to determine if there were any significant differences between the pre- and post-instruction levels of argumentation for each group. The test results indicated that there were no significant differences between the pre-instruction and post-instruction levels of argumentation for the control group $T = 21$, $z = -0.187$ (corrected for ties), N-ties = 10, and $p = 0.851$ (two-tailed) > 0.05. However, the Wilcoxon Signed Rank Test indicated that there was a significant difference between the pre- and post-instruction levels of argumentation for the experimental group $T= 0$, $z = -3.236$ (corrected for ties), N-ties = 6, and $p = 0.001$ (two-tailed) < 0.05.

The Mann-Whitney U-test was performed in order to determine if there were any significant differences between the control and the experimental group's pre-instruction and then post-instruction patterns for the argumentation level dependent variable. Before instruction, the Mann-Whitney U-test results showed that there weren't any significant differences between the argumentation levels of the experimental group (Mean rank = 17.24) and the control group (Mean rank = 21.76, $U = 137.500$, $z = -1.686$ (corrected for ties), $p = 0.092> 0.05$, two-tailed). However post-instruction, the Mann Whitney U-test results indicated that the post-instruction levels of argumentation of the experimental group (Mean rank = 23.76) were significantly different from those of the control group (Mean rank = 15.24), $U = 99.500$, $z = -2.528$ (corrected for ties), $p = 0.011 < 0.05$, two-tailed.

Tables 8 and 9 present the percentages of the pre-instruction and post-instruction argumentation levels for each group. The percentage of Level 0 increased following the genetics instruction for the control group only. The percentages of Level 1 and Level 2 decreased for both groups following the instruction. The percentage of Level 3 increased for both groups following the instruction. The percentage of Level 4 remained null for the control group, whereas this percentage increased for the experimental group following the instruction. The percentage of Level 2 was noticed to be the most common for the control group pre-instruction and post-instruction. In the case of the experimental group, the percentage of Level 2 was noticed to be the most common before instruction while the percentage of Level 3 was noticed to be the most common after instruction.

Table 8

Control Group Students' Percentages of Pre- and Post-Instruction Argumentation Levels

Condition	Level 0	Level 1	Level 2	Level 3	Level 4
Pretest	5.30	5.30	78.90	10.50	0
Posttest	15.80	0	52.60	31.60	0

Table 9

Experimental Group Students' Percentages of Pre- and Post-Instruction Argumentation Levels

Condition	Level 0	Level 1	Level 2	Level 3	Level 4
Pretest	15.80	10.50	73.70	0	0
Posttest	5.30	0	26.30	47.40	21.10

Second Research Question: English Language Proficiency and Students' Argumentation Skills

The English language proficiency of the students was determined by checking their overall average grades in the English subject matter. An average grade in English language was calculated based on all the oral and written assessments that were carried out in English classes. Based on the calculated overall average grades, the students were classified into an English language proficiency category (i.e. high, intermediate, or low). Students who had an overall average grade of less than 12 out of 20 were considered as low achievers. Students who had an overall average grade between 12 out of 20 and 15.99 out of 20 were considered as intermediate level achievers. Students who had an overall average grade of 16 out of 20 or above were considered as high achievers. These categories were set based on the English teacher's suggestion. Figure 2 illustrates the percentage distribution for the English language categories. Table 10 also presents the mean argumentation pretest and posttest scores for the different English language categories.

Table 10

Mean Argumentation Pretest and Posttest Scores for the Different English Language Categories

English language proficiency categories	Argumentation	*Mean*	*Std. Deviation*
Low	Pretest	1.67	.71
	Posttest	2.00	.87
Intermediate	Pretest	1.79	.13
	Posttest	2.52	.19
High	Pretest	2.00	.00
	Posttest	4.00	.00

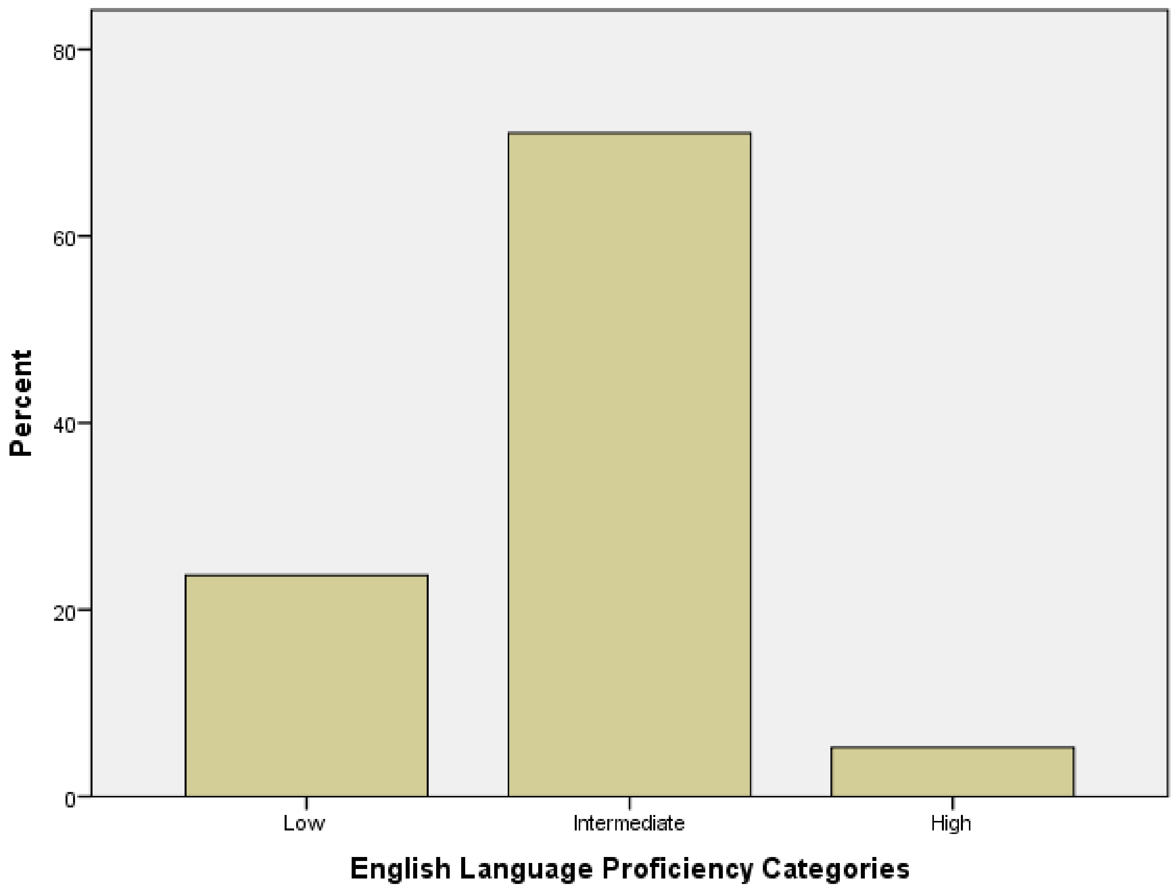

Figure 2. Percentage distribution for English language proficiency categories

In order to assess the effect of English language proficiency on students' argumentation skills, one-way ANOVA was carried out using the pretest and posttest argumentation categorizations as the dependent variables. The results of the one-way ANOVA showed no significant differences between the three English language proficiency groups on the argumentation pretest with an *F* ratio of 0.189 and a significance of 0.829 > 0.05. However, the results of the one-way ANOVA showed a significant difference between the three English language proficiency groups on the argumentation posttest with an *F* ratio of 3.326 and a significance of 0.048 < 0.05. Tukey HSD post hoc test was then conducted in order to determine the source of the differences between the three English language proficiency groups. Results of the Tukey's HSD indicated that the high English language proficiency students' mean argumentation posttest scores differed significantly from the low English language proficiency students with a significance of 0.037 < 0.05. No other significant differences were noted. Table 11 presents the results of the Tukey HSD post hoc test.

Table 11

Tukey HSD Post Hoc Test Results

(I) English Language Proficiency Categories	(J) English Language Proficiency Categories	Mean Difference (I-J)	Std. Error	Sig.
Low	Intermediate	-.41	.382	.541
	High	-2.00*	.776	.037
Intermediate	Low	.41	.382	.541
	High	-1.59	.728	.087
High	Low	2.00*	.776	.037
	Intermediate	1.59	.728	.087

Figure 3 represents a graph of the students' mean argumentation scores on the pretest and posttest. The slope of both lines indicates that the students of all three English language proficiency categories (low, intermediate, and high) have improved on their mean argumentation scores, however the greater gradient of the line representing the high level group shows a better improvement in their argumentation abilities than the low and intermediate level groups.

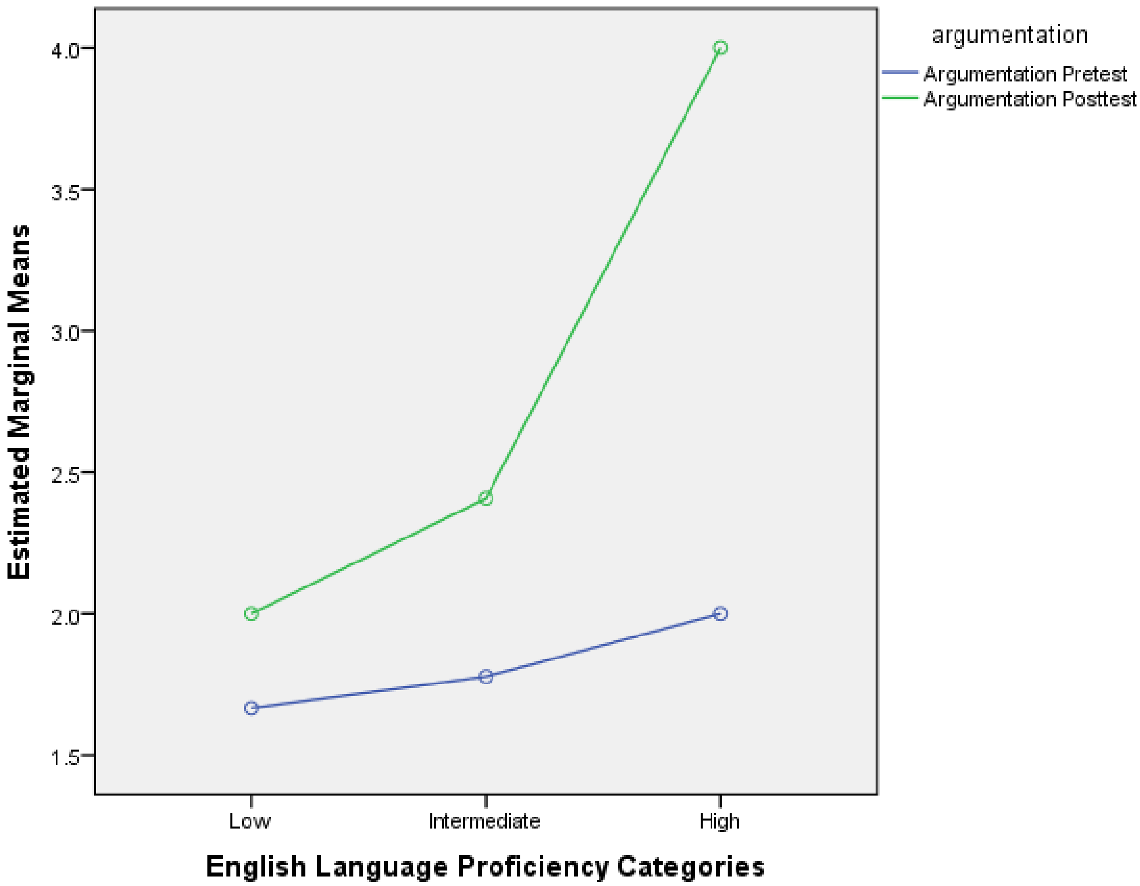

Figure 3. Mean argumentation scores on the pretest and posttest for low, intermediate, and high English level students

Third Research Question: Conceptual Understanding of Genetics

The students completed the genetics content knowledge test before instruction and after instruction. The pre-instruction and post-instruction scores were then entered into the SPSS database. The mean score of the pretest for the experimental group was found to be 18.53, while that of the control group was found to be 20.16 out of a maximum score of 55. The mean score of the posttest for the experimental group was found to be 32.00, while that of the control group was found to be 28.68 out of a maximum score of 55. Table 12 presents the mean pretest and posttest scores and standard deviations for both groups. The paired samples test was carried out, and the results showed that the students' mean scores on the genetics content knowledge test for both experimental and control groups improved significantly ($p=0.000<0.05$). This result was expected since all of the students were studying genetics during the period between the pre-instruction and post-instruction assessments.

Table 12

Descriptive Statistics for the Pretest and Posttest Genetics Content Knowledge Results

Condition	Group	Mean	Std. Deviation
Pretest	Control	20.16	7.71
	Experimental	18.53	6.57
Posttest	Control	28.68	6.60
	Experimental	32.00	7.94

Prior to the ANCOVA test, the Levene's test for equality of variances was performed. The Levene test results were positive ($p=0.074>0.05$) which indicated that there were no significant differences on the pretest scores between the control and the experimental group. Therefore, the assumptions for ANCOVA were met and the test was carried out. The Levene's test results are shown in Table 13. A pretest and posttest data analysis with ANCOVA was then performed. The results indicated that when controlling the pretest, there was a significant difference in the scores of the posttest between the experimental group and the control group ($p=0.032< 0.05$). This indicates that the gain in the experimental group students' mean scores on the genetics content knowledge test was significantly more than the gain in the control group students' mean scores. The results of the ANCOVA test are represented in Table 14.

Table 13

Levene's Test of Equality of Error Variances

F	df1	df2	Sig.
3.39	1	36	.074

Table 14

Univariate ANCOVA for Pretest and Posttest Scores

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	802.98[a]	2	401.49	11.50	.000
Intercept	1487.18	1	1487.18	42.61	.000
Pretest	698.53	1	698.53	20.01	.000
Group	174.83	1	174.83	5.01	.032
Error	1221.57	35	34.90		
Total	37009.00	38			
Corrected Total	2024.55	37			

a. R Squared = .397 (Adjusted R Squared = .362)

Figure 4 represents a graph of the experimental and control groups' mean genetics content knowledge scores. The slope of both lines indicates that both groups have improved on their mean scores, however the greater gradient of the line representing the experimental group shows a better improvement in their genetics content knowledge than the control group.

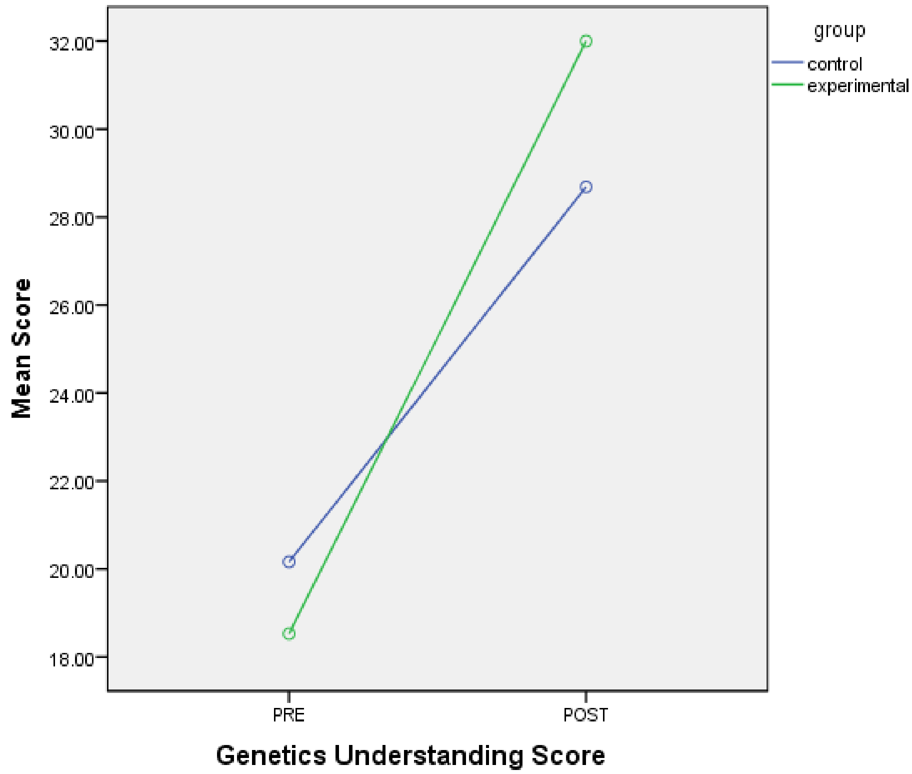

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Figure 4. Mean pre-instruction and post-instruction scores for the experimental and control group on the genetics content knowledge test.

CHAPTER V

DISCUSSION

As previously mentioned, the primary purpose of this study was to further investigate the effect of explicit argumentation instruction on high school students' argumentation abilities and conceptual understanding of genetics. The study also examined the effect of English language proficiency on Lebanese students' acquisition of argumentation skills. A major finding of this study was that explicit argumentation intervention positively affected high school students' conceptual understanding of genetics. Prior to instruction, the mean scores of the experimental group students (Mean score = 18.53) and the control group students (Mean score = 20.16) did not show any significant difference. The post-instruction test scores of both groups improved. However, the experimental group's mean score (Mean score = 32.00) improved significantly more than the control group's mean score (Mean score = 28.68). Knowing that the unit on biological identity and genetic information was over a period of 10 weeks, the increase in the mean scores of both groups was expected. It is not surprising that the students of both groups had an improved genetics content knowledge post-instruction since all of the students were studying genetics during the period between the pre-instruction and post-instruction assessments. However, the reason for the significantly better improvement in the case of the experimental group compared to the control group will be further discussed.

The experimental group students experienced explicit argumentation instruction and were involved in oral discussions (whether in pairs or as a whole-class) about socio-scientific issues within the field of genetics. This intervention allowed the students to get further engaged with the concepts covered in the instructional unit and share their ideas in public. These ideas were debated and analyzed by others. Students were motivated to state their claims and persuade their fellow classmates of their viewpoints. The teacher prompted the students to provide justifications to support their claims. She questioned them about the validity of their justifications and encouraged them to state if they had any possible counterarguments. The teacher also encouraged the students to reflect on the discussion and asked them in case they changed their claims. This process allowed the students to develop the quality and in-depth understanding of the genetics topics that were explored.

As previously mentioned, the intervention included argumentative activities that were directly related to the content of the unit. The students were provided with several opportunities to explore various genetic diseases and discuss the underlying causes behind these diseases. The various dilemmas that were explored during these sessions allowed the students to actually transfer their acquired content knowledge regarding gene mutations into practical real life contexts. In other words, the whole-class discussions allowed the students to develop further their understanding of the notion that gene mutations which result from mild errors in the sequence of nitrogenous bases of a DNA fragment might lead to an inherited genetic abnormality. The discussions also allowed the students to comprehend that an innate genetic abnormality is inherited and cannot be cured. The argumentation intervention, in general, allowed the students to understand the concept of a gene mutation and its subsequent effect on the human body.

Posner et al. (1982) also reported that teaching strategies that engender cognitive conflicts among students enhance their conceptual understanding of science topics. They explained that teaching strategies must be modified in order to promote accommodation rather than recall and assimilation. Teachers must develop demonstrations, real-life problems, or lab activities which assist the students in determining if their concepts are inadequate or must be replaced by new central concepts. The argumentation intervention in this study provided room for cognitive conflict. The argumentative discussions allowed the students to think aloud about their claims and support them with evidence in a well-structured argument. The students were thus provided with an opportunity that allowed them to discover if they held any possible inconsistent scientific concepts related to gene mutations, genetic diseases, and/or gene cloning.

Moreover, according to Osborne (2010), argumentation assists in addressing misconceptions. When students are asked to argue for another position they will have to think deeply about the alternative concepts, compare and contrast their arguments against various conceptions, explain the resulting information, and consider issues and arguments. The argumentation intervention in this study might have helped the students further discover if they held any incorrect scientific claims, because they were required to explain in a whole-class discussion their understanding of complex terms such as genes, DNA, mutations, and cloning in a coherent and scientifically accurate manner. Students were also required to make logical and appropriate connections between these various concepts when they attempted to persuade their fellow classmates of their viewpoints. Students who thus had incorrect scientific notions were subject to opposing views from their fellow classmates. The subsequent debate that took place in class allowed the students to identify the inconsistencies in their claims, eliminate the inconsistent ideas, and accommodate new logical scientific ideas instead.

It is important to mention as well that the intervention period of this study was applied during four sessions only. Another important finding is that a short exposure to explicit argumentation instruction was noticed to be significant enough in promoting secondary students' conceptual knowledge of genetics. This finding is consistent with those of Lewis and Leach (2006) who claimed that a brief argumentation intervention period that is well designed and related to the concepts of the unit is effective enough in enhancing students' content knowledge. The findings of this study are also consistent with those of Sadler and Fowler (2006) who reported that a short exposure to argumentation is effective in enhancing students' conceptual knowledge if they have the required "threshold level of knowledge" of the chosen scientific topics. Findings of this study also support the claim that the application of an explicit argumentation intervention towards the end of a unit has a positive impact on students' conceptual knowledge of the unit topics, because students have the adequate pre-requisite content knowledge that would allow them to engage in effective argumentative discussions. It is important to emphasize again that a short duration of an argumentation intervention was noticed to be significant enough in promoting secondary students' conceptual knowledge of genetics. This means that this instructional strategy can be applied in the Lebanese context and specifically in life science classes. The intervention only requires a minor modification in the teaching strategy that is adopted in the unit on biological identity and genetic information. Such an instructional strategy does not affect the life science content that is usually covered in grade 11 scientific section classes based on the Lebanese curriculum. Hence, the intervention does not prevent the teacher from covering all the national curriculum content within the usual assigned duration.

Another major finding of this study is that an explicit argumentation intervention is effective in enhancing students' argumentation skills. The results of this study indicated that the post-instruction levels of argumentation of the experimental group were significantly higher than those of the control group. The percentage of Level 2 argumentations that consist of a claim, data, and/or warrant according to Dawson and Venville (2010) argumentation categorizations was noticed to be the most common for the control group before instruction and after instruction. In the case of the experimental group, the percentage of Level 2 (73.7%) argumentations was noticed to be the most common before instruction while the percentage of Level 3 (47.4%) argumentations that consist of a claim, data/warrant, and backing or qualifier according to Dawson and Venville argumentation categorizations was noticed to be the most common after instruction. The percentage of Level 4 argumentations that consist of a claim, data/warrant, backing, and qualifier based on Dawson and Venville categorizations remained null for the control group, whereas this percentage increased for the experimental group (21.1%) following the argumentation intervention.

The improvement in the argumentation skills exhibited by the experimental group students may be due to the fact that these students received direct instruction on argumentation. Argumentation was explicitly defined, and Toulmin's argumentation model was introduced. The students were also provided with several opportunities to develop their argumentation skills. They solved worksheets and engaged in whole-class argumentative discussions that were contextualized and well-designed. During the argumentative discussions, the teacher reminded the students of the various components of argumentation based on Toulmin's model. She also thoroughly questioned the students and encouraged them to state aloud their claims. Students were also encouraged to provide justifications to support their claims. The improvement in the experimental group students' argumentation skills was thus expected after the argumentation intervention. It was anticipated that these students would exhibit more of Level 3 and Level 4 arguments post-instruction. This finding is consistent with Dawson and Venville (2013) who reported that explicit argumentation instruction is effective in promoting the quality and complexity of students' argumentation skills. It is also important to state that the experimental group students were exposed to argumentation instruction within four sessions only. The argumentation skills of these students thus developed within a short exposure to argumentation. This finding is consistent with the claim that was made by Kuhn (1991). Kuhn explained that a brief intervention on argumentation is effective enough and can result in significant changes in students' argumentation skills. According to Lewis and Leach (2006) as well, argumentation skills are intrinsically present within students and can develop significantly in a short period of time if students are provided with opportunities during which they engage in argumentative discussions that are directly related to the context of the instructional unit and to the students' personal experiences.

The present study also examined the effect of English language proficiency on Lebanese students' acquisition of argumentation skills. As previously mentioned, all of the students involved in the study were classified into an English language proficiency group based on all the oral and written assessments that were carried out in English classes. Students who had an overall average grade of less than 12 out of 20 formed the low level English language proficiency group. Students who had an overall average grade between 12 out of 20 and 15.99 out of 20 formed the intermediate level English language proficiency group. Students who had an overall average grade of 16 out of 20 or above formed the high level English language proficiency group. Descriptive statistics indicated that the percentage distribution of the Intermediate level English language proficiency group was the highest among the three groups. The mean argumentation scores of the high English language proficiency students were noticed to be the highest on the argumentation pretest (Mean score = 2.00), while the mean argumentation scores of the low English language proficiency students (Mean score = 1.67) were the lowest on the argumentation pretest. The differences between the three groups on the argumentation pretest were not statistically significant though ($p > 0.05$). Students of all three English language proficiency categories showed improved mean argumentation scores on the argumentation posttest. However, students of the high English language proficiency category exhibited the highest mean scores on the posttest (Mean Score = 4.00) in comparison to the intermediate level English language proficiency students (Mean Score = 2.51) and the low level English language proficiency students (Mean Score = 2.00). The differences between the three English language proficiency groups on the argumentation posttest were statistically significant ($p < 0.05$). Results of the Tukey's HSD indicated that the high level English language proficiency students' mean argumentation posttest scores differed significantly from the low level English language proficiency students ($p < 0.05$). However, no other significant differences were noted.

These results indicate that the students of all three English language proficiency categories developed their argumentation skills as a result of the intervention. This means that the argumentation intervention can be applied in Lebanese life science classes knowing that most of the students might have an intermediate and low level English language proficiency since English language is not the mother tongue of these students. Nevertheless, all of the students benefit from the argumentation intervention and will show improvements in their argumentation skills. It is important to stress as well that the results of this study have indicated that high level English language proficiency students made more progress than intermediate and low level English language proficiency students. The high level English language proficiency students showed a better improvement in constructing warrants, backings, and qualifiers than intermediate and low level English language proficiency students after the argumentation instruction. Explicit argumentation instruction thus seems to have a differential effect on students based on their language capabilities, with high and intermediate English language ability students benefiting more than low English language ability students. This finding is in accordance with Lin and Mintzes (2010) who reported that students' argumentation skills are strongly related to their language capabilities. These researchers explained that argumentation is a language-based activity which means that the students must utilize their language skills in order to express their thoughts whether verbally or in writing. Students' language capabilities must be taken into consideration when investigating their argumentation skills. Cummins (1981) also claimed that it is important to consider the students' language proficiency as a significant individual difference. According to Cummins, high level English language proficiency students benefit most from oral classroom discussions related to abstract ideas and controversial topics while students of low English language proficiency might be at a disadvantage when such strategies are implemented.

It is important to stress as well that the students who were involved in this study were practicing argumentation in English language which is not their mother tongue language. Even though most of the students had an acceptable intermediate level of English language proficiency, it was still not an easy task to state in public their claims and justify them in a language that was not their own. Some students also attempted to state their claims during the whole-classroom discussions in Arabic, because they were capable of articulating their thoughts using their mother tongue language more confidently and clearly. The non-native language proficiency of these students seems to be a variable that affected their engagement in argumentative discussions and the development of their argumentation capabilities. This finding is supported by Scholtz, Braund, Hodges, Koopman, & Lubben (2008) who claimed that effective argumentation strongly depends on the group dynamics or the status of the individuals within a group in terms of their pre-requisite content knowledge and language proficiency. Students who have a sophisticated pre-requisite content knowledge and a high level of language proficiency are considered as higher status members. These students tend to benefit more from open-ended classroom discussions and might even play an authoritative role and restrict others from expressing their thoughts. According to these researchers, the instructor must thus be highly supportive, frequently available, and well prepared in order to help disadvantaged students in overcoming their difficulties. Sadler and Fowler (2006) also reported that argumentation instruction is more effective in college rather than high school, because college students have a more developed and well-organized body of knowledge than high school students. Findings of the present study indicate that the language proficiency (whether native or non-native) varies among the students, and this variable must be taken into consideration as a significant individual difference that might affect the students' engagement in argumentative discussions. The high school students' language capabilities in the study that was conducted by Sadler and Fowler were not taken into consideration. This variable might have been a subtle factor that affected the high school students’ acquisition of argumentation skills and their engagement in the argumentative discussions. High school students’ less developed language proficiency might have thus been one of the contributing factors that led them to benefit less than the college students from the argumentation intervention. In other words, students’ language proficiency must be taken into consideration as a significant variable that affects their acquisition of argumentation skills.

Conclusion

The present study examined the effect of explicit argumentation instruction on high school students’ argumentation abilities and conceptual understanding of genetics. The study also examined the effect of English language proficiency on Lebanese students’ acquisition of argumentation skills. Findings of this study indicate that explicit argumentation instruction enhances high school students’ argumentation skills and conceptual understanding of genetics. Results also indicate that Lebanese high school students’ English language proficiency serves as a predictor to their success in learning argumentation.

Limitations

The present study has several inevitable limitations. The study was conducted with a small sample size, so the generalizability of the findings is limited to some degree. It is recommended to conduct further studies with a larger sample size in order to generalize the results. It is important to state as well that the intervention period consisted of four sessions only due to the packed Lebanese curriculum in grade 11 scientific section. The intervention period might have been a short duration in order to promote the acquisition of Level 4 arguments among the students. Hence, it is recommended to conduct further longer studies on argumentation that incorporate a variety of argumentative topics which are related to the units being explored in order to promote the students' argumentative abilities. A further limitation of the study is that there was only one teacher who delivered the argumentation instruction. It was not possible to determine whether the improvement in the students' argumentation skills was due to qualities of the teacher other than the argumentation intervention that she applied. The participation of more than one teacher in future studies is thus recommended in order to overcome the possibility of a teacher effect. It is also important to state that the results are limited to the participants involved in the study and the socio-scientific contexts within which explicit argumentation intervention was applied. Hence, it is recommended to conduct further studies on argumentation within the field of other socio-scientific and scientific topics.

Implications

The findings of this study may help educators to better plan their instructional approaches in high school science classes in order to enhance conceptual understanding and eventually academic achievement. Furthermore, findings of this study provide valuable insights about the effects of non-native language proficiency on high school students' argumentation skills and achievement. This study has made a unique contribution to the field in that it is possibly the first study conducted in the Arab region - according to the literature review conducted for the purposes of this study - that has explored the effect of non-native English language proficiency on high school students' argumentation skills in science classes. There are also very few studies in the literature that have explored non-native language proficiency as an individual difference during the teaching of argumentation in science classes. One major implication for teaching is to consider the non-native language proficiency of high school students beforehand as a significant individual difference when planning to implement whole-classroom discussions in science classes. An interesting goal for future research would be to conduct additional studies in this particular field in order to identify how best to plan for instruction in science classes and apply it effectively. It is recommended to further investigate the effect of the utilization of native language versus non-native language during the teaching of argumentation in science classes.

APPENDIX A

EXPERIMENTAL GROUP LESSON PLANS

Introducing Argumentation and Toulmin's Model (First Session)

Purpose

This lesson will introduce the students to argumentation. They will explore the meaning of argumentation and its various components based on Toulmin's model. The lesson will allow the students to identify the components of a scientific argument, develop their own arguments, and argue against different views.

Science Content and Major Concepts

The students will be introduced to Toulmin's Model of Argumentation and its various components (content is attached within Appendix C).

Instructional Objectives

By the end of the lesson, the students will be able to:

- Define argumentation
- Identify the components of argumentation based on Toulmin's model
- Develop their argumentation skills

Entrance Abilities

The lesson does not require any pre-requisite abilities necessary to attain its objectives, because it is not directly related to the content of the unit. The lesson focuses on a topic that is related to the students' daily living.

Materials and Equipment

Prepared handouts (Appendix C)

Instructional Activities

Set induction. The teacher will first implement a short exercise as a brainstorming activity. In this exercise, the students will reflect on their different perceptions of argumentation. They will first solve the exercise (worksheet is in Appendix C) individually and then discuss their answers with a partner identifying any points of agreement/disagreement before a whole classroom discussion is raised. During the classroom discussion, the teacher will pinpoint the common perception based on the students' responses. She will then define argumentation and relate it to the field of science.

Other instructional activities. The teacher will then explicitly introduce Toulmin's argumentation model through a short exercise. The students will be asked to construct a concise well-written argument in an attempt to answer the following question: "Do you think that smoking in public places should be banned?" In their response, the students must make sure to state their choice and support it with as many reasons as possible. The students will first work individually and construct their own arguments. They will then discuss their answers with a partner in order to evaluate the adequacy of each other's argument before a whole classroom discussion is raised. During the classroom discussion, the students will have a chance to share their different points of view. The teacher will also guide the discussion in a way where the various components of Toulmin's argumentation model get revealed. She will illustrate in a structured diagram the discussed argument and will fill in the various components of Toulmin's argumentation model so that the students familiarize themselves with the terms.

Closure and review. The various argumentation components will be summarized, and the students will receive a handout (Appendix C) that contains information describing each component along with a diagram of Toulmin's model.

Assessment of Instructional Objectives

In this lesson, the students' understanding of argumentation and its components will be informally assessed during the classroom discussion. The students' understanding of argumentation will be further assessed during the following sessions.

Cystic Fibrosis Scenario (Second Session)

Purpose

This lesson allows the students to utilize their acquired argumentation skills within a socio-scientific genetic disorder. The students will be aware of various genetic disorders, and they will reinforce their acquired argumentation skills in a classroom activity that addresses one of the genetic disorders.

Science Content and Major Concepts

The content presented within this lesson includes information about various genetic disorders (presented in the textbook) and genetic therapy (attached within appendix C).

Instructional Objectives

By the end of the lesson, the students will be able to:

- Enhance their awareness of genetic disorders
- Practice and develop their acquired argumentation skills within a socio-scientific issue

Entrance Abilities

Students must be familiar with the terms homozygote, heterozygote, dominant, recessive, genotype, and phenotype.

Materials and Equipment

- Prepared worksheets (see Appendix C)
- Textbook

Instructional Activities

Set induction. Early at the beginning of this session, the teacher will explain about the major genetic disorders that are presented in the textbook. She will then remind the students briefly of the previously discussed Toulmin (1958) argumentation model components. The teacher will then state that these three sessions help the students further explore argumentation within the field of genetics socio-scientific issues.

Other instructional activities. After discussing various genetic disorders, the students receive a worksheet about cystic fibrosis. They are asked to read the information in the worksheet and answer the first two questions individually where they have to state their opinion regarding the issue and justify their decisions. The teacher will then lead a whole classroom discussion combined with periods when the students answer again individually the rest of the questions in the handout.

Closure and review. At the end of the lesson, the teacher will summarize major ideas discussed during the session.

Assessment of Instructional Objectives

In this lesson, the students' acquired argumentation skills and understanding of the socio-scientific topic are assessed informally by checking their worksheet answers and their views during the classroom discussion.

Gene Mutation Dilemma (Third Session)

Purpose

This lesson allows the students to utilize their acquired argumentation skills within the field of genetic mutations. The students will be introduced to a genetic mutation dilemma, and they will reinforce their acquired argumentation skills in a classroom discussion on that topic.

Science Content and Major Concepts

The content presented within this lesson includes information about genetic mutations and genetic testing (information on the topic is attached within appendix C).

Instructional Objectives

By the end of the lesson, the students will be able to:

- Relate their conceptions of genetic mutations to genetic disorders
- Practice and develop their acquired argumentation skills within a socio-scientific issue

Entrance Abilities

Students must be familiar with the terms homozygote, heterozygote, dominant, recessive, genotype, phenotype, genetic mutations, and gene polymorphism.

Materials and Equipment

Prepared worksheets (see Appendix C)

Instructional Activities

Set induction. Early at the beginning of this session, the teacher will remind the students briefly of the previously discussed information about genetic mutations and gene polymorphism. The different types of mutations will be reviewed, and the teacher will explain that the classroom activity allows the students to explore the effect of gene mutations on a person's health.

Other instructional activities. The students will receive a worksheet about a genetic mutation condition. They are asked to read the information in the worksheet and answer the first two questions individually where they have to state their opinion regarding the issue and justify their decisions. The teacher will then lead a whole classroom discussion combined with periods whereby the students answer again individually the rest of the questions in the handout.

Closure and review. At the end of the lesson, the different types of genetic mutations and disorders are reviewed. The students are also asked to review the material related to genes and protein synthesis that was discussed in earlier sessions for the next class.

Assessment of Instructional Objectives

In this lesson, the students' acquired argumentation skills and understanding of the socio-scientific topic are assessed informally by checking their worksheet answers and their views during the classroom discussion.

Gene Cloning (Fourth Session)

Purpose

The purpose of this activity is to enhance students' understanding of the concept of gene cloning. The lesson will reinforce students' content knowledge of gene cloning and will introduce them to recent applications in that field. The classwork activity will allow the students to identify the potential benefits and risks of genetically modified food. The activity also provides the students with an opportunity to argue their views in regards to the topic.

Science Content and Major Concepts

The content presented within this lesson includes information about gene cloning (presented in the textbook) and genetically modified food (in appendix C).

Instructional Objectives

By the end of the lesson, the students will be able to:

- Reinforce their conceptions of gene cloning
- Explore applications of DNA technology
- Practice and develop their acquired argumentation skills within a socio-scientific issue

Entrance Abilities

Students must be familiar with the concept of genes, protein synthesis, and gene cloning

Materials and Equipment

Textbook and prepared worksheets (see Appendix C)

Instructional Activities

Set induction. Early at the beginning of this session, the teacher will remind the students briefly of the previously discussed information about genes and their critical role in protein synthesis. The teacher will discuss the procedure of gene cloning (case of insulin) presented in the textbook, and she will show the students a video of recent applications of gene cloning in the field of medicine and agriculture in order to introduce them to the day's lesson. The teacher will then explain that the classroom activity allows the students to explore the application of DNA technology in an aspect that is directly related to their daily living.

Other instructional activities. The students will then receive a worksheet about a genetically modified plant issue. They are asked to read the information in the worksheet and answer the first two questions individually where they have to state their opinion regarding the issue and justify their decisions. The teacher will then lead a whole classroom discussion combined with periods whereby the students answer again individually the rest of the questions in the handout.

Closure and review. At the end of the lesson, major concepts discussed during the session are summarized along with a revision of Toulmin's model.

Assessment of Instructional Objectives

In this lesson, the students' acquired argumentation skills and understanding of the socio-scientific topic are assessed informally by checking their worksheet answers and their views during the classroom discussion.

APPENDIX B

CONTROL GROUP LESSON PLANS

Genetic Disorders (Sessions One and Two)

Purpose

This activity will expose the students to various genetic disorders through guided research. The students will use their textbook and the internet in order to research about the causes and consequences of a specific genetic disorder. They will also create a two pages medical sheet that describes information about the disorder similar to a disease fact sheet that is usually given to a patient in order to quickly find out facts about a particular genetic disorder.

Science Content and Major Concepts

This lesson will introduce the students to various genetic disorders such as Huntington disease, cystic fibrosis, sickle cell anemia, and Duchenne muscular dystrophy. Genetic disorders are diseases that are caused by a defect in a person's genetic material (DNA). Information regarding these disorders is presented within the students' textbooks.

Instructional Objectives

By the end of the lesson, the students will be able to:

- Research genetic diseases
- Identify the causes and consequences of different genetic diseases
- Create a fact sheet about their findings
- Share their findings with their classmates

Entrance Abilities

Students must be familiar with the terms homozygote, heterozygote, dominant, recessive, genotype, and phenotype.

Materials and Equipment

- Internet access
- Textbook

Instructional Activities

Set induction. Early at the beginning of this session, the teacher will remind the students briefly of the previously discussed information on phenotype and genotype. The teacher will explain that the next two sessions will provide the students with a chance to be aware of several types of genetic disorders.

Other instructional activities. In the first session, the students will be asked to go to the school's library where there is internet access and conduct a research in groups regarding one of several suggested genetic disorders. In their research, the students must bring information related to the cause, diagnosis, and treatment. The students are then asked to create a two pages medical fact sheet that can be given to a patient in order to explain briefly and clearly about his/her disorder. In the next session, the students are asked to discuss the information that they have researched in the previous session and submit their medical sheets.

Closure and review. At the end of the lesson, the students are reminded of the previously discussed genetic disorders.

Assessment of Instructional Objectives

The teacher will assess the students' attainment of the lesson's instructional objectives by checking the validity of the information presented in their medical sheets.

Genetic Disorders Classwork (Third Session)

Purpose

The purpose behind this session is to reinforce the students' acquired conceptions of phenotype, genotype, gene mutations, and genetic disorders.

Science Content and Major Concepts

The content presented within this lesson includes information about various genetic disorders and gene mutations (worksheet is attached within appendix C).

Instructional Objectives

By the end of the lesson, the students will be able to:

- Differentiate between genotype and phenotype
- Reinforce their awareness of genetic disorders
- Reinforce their conceptions of gene mutations

Entrance Abilities

Students must be familiar with the terms homozygote, heterozygote, dominant, recessive, genotype, phenotype, gene mutations, and gene polymorphism.

Materials and Equipment

Prepared worksheets (see Appendix C) and the textbook for reference

Instructional Activities

Set induction. Early at the beginning of this session, the teacher will remind the students briefly of the previously discussed information on phenotype, genotype, gene mutations, and genetic disorders. The teacher will also explain that the classwork activity allows the students to explore the effect of gene mutations on a person's health.

Other instructional activities. The students are asked to solve the worksheet questions individually as a reinforcement for their previously acquired content knowledge. After they solve the questions, the students will share their answers in a whole classroom discussion. During the discussion, the teacher will pinpoint and explain the correct answers.

Closure and review. At the end of the lesson, the students are reminded of the previously discussed content. The teacher will summarize briefly major topics of the lesson.

Assessment of Instructional Objectives

In this lesson, the students' understanding of the presented material is assessed informally by checking their worksheet answers and the discussion that might evolve around each question.

Gene Cloning (Fourth Session)

Purpose

The purpose of this activity is to enhance students' understanding of the concept of gene cloning. The lesson will reinforce the students' content knowledge of gene cloning and will introduce them to recent applications in that field.

Science Content and Major Concepts

The content presented within this lesson includes information about gene cloning (found in the textbook).

Instructional Objectives

By the end of the lesson, the students will be able to:

- Reinforce their conceptions of gene cloning

- Explore applications of DNA technology

Entrance Abilities

Students must be familiar with the concept of genes, protein synthesis, and gene cloning

Materials and Equipment

Textbook and prepared worksheet (Appendix C)

Instructional Activities

Set induction. Early at the beginning of this session, the teacher will remind the students briefly of the previously discussed information about genes and their critical role in synthesizing our body proteins. The teacher will then state that this session allows the students to explore applications of technology in the field of genetics.

Other instructional activities. The students are then asked to read and explore the experiment presented in the textbook that discusses the concept of insulin (gene) cloning. They are then asked to solve the worksheet questions in pair. Afterwards, the teacher will discuss the procedure of gene cloning presented in the textbook. The worksheet questions will be corrected in class, and the students will be given a chance to share and explain their answers.

Closure and review. The teacher will summarize major concepts discussed during the session and will show the students a video of recent applications of gene cloning in the field of medicine and agriculture so that they become aware of various applications of DNA technology nowadays.

Assessment of Instructional Objectives

In this lesson, the students' acquired content knowledge of the topic is assessed by checking their worksheet answers.

APPENDIX C

EXPERIMENTAL GROUP WORKSHEETS

What is Argumentation? (First Session)

This exercise was developed by the Ideas, Evidence and Argument in Science (IDEAS) Project (Osborne, Erduran, & Simon, 2004b) and will be implemented as a brainstorming activity.

Activity

The following table contains several metaphors for people's perceptions of the term "argumentation".

a- Which of the following metaphors is most similar to the way you think about argumentation?

b- State in the comments column the reasons why you do or do not like each of the mentioned metaphors.

Table 15

Definition of Argumentation

Metaphor: Argumentation is like	**Comments**
Brainstorming	
War	
Diplomatic negotiation	
Confrontation	
A roundabout on the road to truth	
An explanation	
A dead end	
(Other suggestions/thoughts)	

Toulmin Model of Argumentation (First Session)

Toulmin (1958) explained that effective scientific argumentation consists of the following six components:

- Claim: A statement that a proposer believes has the status of a certain truth.
- Data: The evidence used to prove an argument and back it up.
- Warrants: General and implicit statements that link the claim with the evidence. Warrants might be rules or principles that are suggested to justify the links between the evidence and the claim.
- Qualifiers: Statements that limit the claim or statements that specify the conditions under which a claim is true.
- Rebuttals: Counter-arguments or statements that indicate the circumstances when an argument does not hold true.
- Backing: Statements that function as assurances and are meant to justify a certain warrant. In other words, these are statements that do not necessarily prove the claim but do prove that a warrant is true.

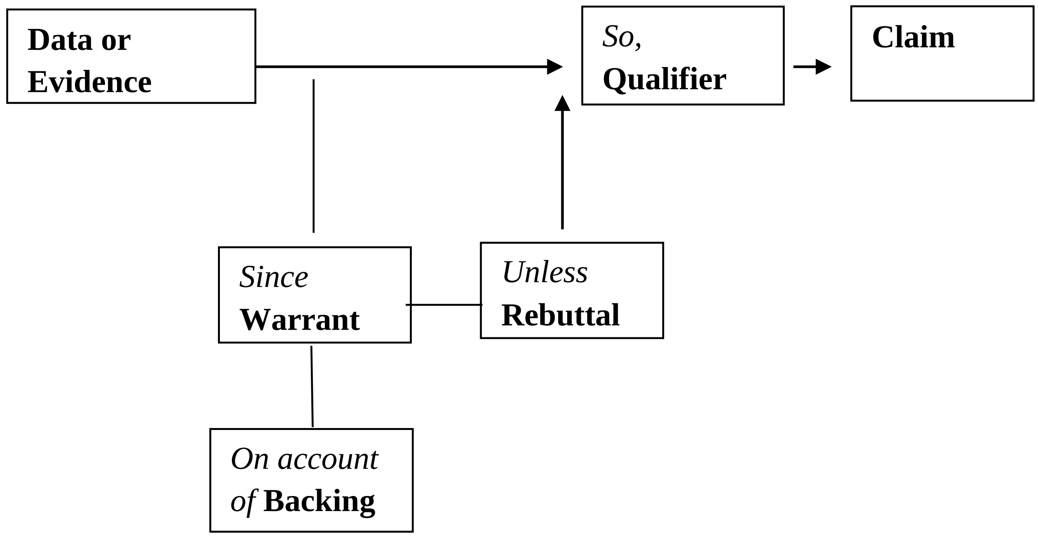

Figure 5. Toulmin's Argumentation Model (Toulmin, 1958, p.104).

Cystic Fibrosis Scenario (Second Session)

The following section presents a cystic fibrosis issue that has been previously utilized in a study conducted by Zohar and Nemet (2002):

Cystic Fibrosis

Cystic Fibrosis (CF) is a prevalent hereditary lung disease. The gene responsible for this disease is autosomal recessive which means that a child must inherit a copy from each parent in order to get the disease. This disease results in a malfunctioning of the external secretion glands which leads to salty sweat, digestion disorders, and excessive mucus secretion. The large quantities of secreted mucus causes recurrent lung infections which eventually results in long-term damage to the lungs. This disease is thus deadly and patients do not usually survive past the age of 40. The gene responsible for this disease has been located, and scientists are now working on genetic therapy.

One idea suggests replacing a healthy gene for the deformed one in the lung tissue. But, the complex branching of the lungs makes it impossible to remove the epithelium cells and then return them after replacing the gene. This technique was successful though in 1992 when one group of scientists inserted the gene into the epithelium of a rat's lung where it continued to function for 6 weeks.

Another idea focuses on the development of a spray which consists of normal genes that are attached to carriers whose role is to insert the genes into the cells. The patients will thus inhale the spray from time to time (hoping that the normal genes will be capable of functioning in the cells). In spite of all these efforts, genetic treatment of CF is still in its early stages and patients will remain in distress in the meantime.

Dilemma

Mr. and Mrs. D both have brothers whom are sick with CF (an autosomal recessive trait). The couple got married and Mrs. D is now pregnant. Genetic tests revealed that the couple are both carriers of CF and that the embryo is homozygous for CF. Mr. and Mrs. D consider whether or not they should have an abortion.

a- Do you think they should perform an abortion?

b- State and justify your decision.

c- Your friend disagrees with you. Define his/her position. How could your friend explain his/her position to convince you that he/she is right?

d- What will you answer your friend? Explain.

Gene Mutation Dilemma (Third Session)

The following section presents a gene mutation dilemma that is adopted from a previous study conducted by Zohar and Nemet (2002).

Huntington Disease

Huntington Disease is a dominant genetic trait which means that affected individuals receive a dominant allele from each parent. The disease is caused by an abnormal gene located on the 4^{th} chromosome. The mutant form of the gene has a sequence of three DNA base pairs (CAG) repeated many times. This three base pair sequence occurs in the normal form of the gene as well but is not repeated that often. Genetic testing nowadays can determine the base sequence of the gene for this disease and count the number of CAG sequences. Those individuals who have a high number of these sequences will develop the disease. Affected individuals usually develop symptoms of this disease between the ages of 35 and 45. Common symptoms of the disease include involuntary muscle tremors and mood changes along with memory loss and even schizophrenia in certain cases. The severity of these symptoms, however, differ from one person to another. Huntington Disease is fatal, and these patients usually die at the age of 50.

Scenario

Mrs. D is a 28-year old female who was recently married. Mrs. D's father has been diagnosed with Huntington five years ago. Mrs. D is now pregnant, and she went for her first visit to the gynecologist. In the discussion about Mrs. D's family history, the doctor asks if she has considered the option of genetic testing in order to determine if she has inherited the gene mutation for this disorder. The doctor explains to Mrs. D that if she does the genetic test, she will know if she has inherited the Huntington disease gene mutation.

However, the test does not determine at what age the symptoms might appear. The doctor also asks Mrs. D if she is worried about the possibility that her baby could be at a risk of having the disease, and if she would like to do a genetic test for her fetus as well.

Mrs. D indicates that she believes there is a lot of research nowadays to find a cure for this disease, and she thinks that a treatment will be developed soon that will help her father recover. She also explains that she fears being discriminated at work if the results turned out to be positive. Mrs. D adds that she does not wish to be tested for herself or her baby.

a- Do you think that Mrs. D should be tested for Huntington Disease?

b- State and justify your decision.

c- Your friend disagrees with you. Define his/her position. How could your friend explain his/her position to convince you that he/she is right?

d- What will you answer your friend? Explain.

Gene Cloning (Fourth Session)

The following section presents a genetically modified plant issue that has been discussed in a previous study conducted by Khishfe (2014):

Genetically Modified Plant Issue

Scientists were capable of developing a new genetically modified plant in an attempt to deal with vitamin A deficiency. This genetically modified plant contains two extra genes. One group of scientists consider that the genetically modified plant which has two extra genes is capable of preventing blindness since it improves vitamin A ingestion. An increased consumption of vitamin A reduces the risk of childhood blindness. This group of scientists argues that there aren't any studies yet which indicate the dangers related to genetically modified food.

On the other hand, another group of scientists believe that we still do not know how consuming genetically modified food will impact our bodies. There isn't yet any biochemical examination of the genetically modified plant and assessment of how adding two genes may have altered the plant as a whole. This group of scientists is also concerned that the new modified strain is planted in the same regions as other natural strains which means that the natural strains might get contaminated and their genetic material could be altered. Thus, these scientists claim that a better solution is to consume a healthy and balanced diet which provides sufficient amounts of vitamin A rather than a genetically modified plant.

a- Do you think that the production of genetically modified plants should be allowed?

b- State and justify your choice.

c- Your friend disagrees with you. Define his/her position. How could your friend explain his/her position to convince you that he/she is right?

d- What would you reply to your friend in order to explain that your decision is right?

Control Group Worksheets

Genetic Disorders Worksheet (Third Session)

The following section consists of a worksheet on genetic disorders. The information presented in this worksheet is adopted from a previous study conducted by Zohar and Nemet (2002).

Cystic Fibrosis

Cystic Fibrosis is a prevalent hereditary lung disease. The gene responsible for this disease is autosomal recessive which means that a child must inherit a copy from each parent in order to get the disease. The normal allele can be represented by "G" and the mutant allele can be represented by "g".

1- Indicate the genotype of an individual with cystic fibrosis.

2- Approximately one in 25 Americans has a mutation in the cystic fibrosis gene. Does this indicate that all of those people will have the disease? Indicate the possible genotypes of people that carry the mutant allele.

Mr. and Mrs. D got married. Neither has cystic fibrosis. However, Mrs. D's sister is very sick with cystic fibrosis. Mrs. D is now pregnant, and the couple are worried that their baby might have cystic fibrosis.

3- Mrs. D's parents do not have cystic fibrosis. Knowing that Mrs. D's sister has the disease, what do you think are the genotypes of each of Mrs. D's parents? Explain how you figured out your answer.

Mr. and Mrs. D decide to do medical tests in order to determine whether any of them carries a mutant cystic fibrosis gene.

4- The results came back that Mrs. D is a heterozygote. Indicate her genotype.

5- Mr. D's results indicate that he is a homozygote. Indicate his genotype.

6- What are the chances that Mr. and Mrs. D's children will have cystic fibrosis? Explain your answer.

Huntington Disease

Huntington Disease is a dominant genetic trait which means that affected individuals receive a dominant allele from each parent. The disease is caused by an abnormal gene located on the 4^{th} chromosome. The mutant form of the gene has a sequence of three DNA base pairs (CAG) repeated many times. This three base pair sequence occurs in the normal form of the gene as well but is not repeated that often.

Mrs. D is a 28-year old female who was recently married. Mrs. D's father has been diagnosed with Huntington five years ago. Mrs. D is now pregnant, and she went for her first visit to the gynecologist.

1- What are the chances that Mrs. D develops Huntington disease later in her life if she is a heterozygote for this gene?

2- What are the chances that Mrs. D's children will inherit the mutant form of the gene from their mother if she is a heterozygote?

3- Use the genetic codes table in your textbook in order to determine the amino acid that is repeated often in the mutant gene of Huntington disease.

4- Explain why Huntington disease is seldom lethal.

Gene Cloning (Fourth Session)

Instructions

Read the information presented in the textbook on gene cloning and answer the following questions:

1- Describe the experimental procedure presented.

2- What is insulin?

3- Define the term transgenic organism.

4- What kinds of proteins are synthesized by the mouse?

5- What can you deduce from this experiment?

6- Identify other applications of gene cloning.

APPENDIX D

STUDENT SURVEY

This survey is adopted from a study conducted by Dawson and Venville (2010). The students are asked to read the following dilemma and answer the subsequent question.

Designer Babies Dilemma

A designer baby is created through gene therapy. It is defined as a baby whose genetic makeup has been artificially selected by genetic engineering combined with in-vitro fertilization in order to ensure the presence or absence of particular genes. Parents might choose to undergo this procedure in order to prevent passing on diseases to their children. Some parents might also decide to use this technology in order to choose the gender of their baby. With technological advances, this procedure will allow parents to select many other traits of their baby such as height, hair color, eye color, and a lot more.

In a well-written paragraph, answer the following question: Do you think such use of gene technology should be allowed? In your response, make sure to state your claim and support it with as many reasons as possible.

Genetics Content Knowledge Test

Multiple Choice (grade is out of 21)

The following multiple choice questions have been adopted from the TBGC that was constructed by Sadler (2004). Students are requested to read and circle the response which best answers each question.

1. Which of the following does NOT contain genetic material?
   a. mushroom
   b. oxygen
   c. tomato
   d. tree
   e. virus

2. Of the human cells listed below, which contain DNA?
I. blood cells II. brain cells III. liver cells IV. reproductive cells
   a. I only
   b. II only
   c. II and IV only
   d. I, II, and IV only
   e. I, II, III, and IV

The nerve cells of a particular animal species contains 20 chromosomes. Use this information to answer the questions 3-6.

3. How many chromosomes would an unfertilized egg cell from this species contain?
   a. 0
   b. 5

c. 10
d. 20
e. 40

4. How many chromosomes would a fertilized egg cell from this species contain?
   a. 0
   b. 5
   c. 10
   d. 20
   e. 40
5. How many chromosomes would a skin cell from this species contain?
   a. 0
   b. 5
   c. 10
   d. 20
   e. 40
6. How many chromosomes does any one individual animal from this species inherit from its father?
   a. 0
   b. 5
   c. 10
   d. 20
   e. 40
7. Which statement most accurately describes the function of genes?
   a. genes control the production of DNA
   b. genes control the production of protein
   c. genes control cellular movement
   d. genes control brain activity
8. Where in a cell is DNA located? (Assume the cell is eukaryotic.)
   a. cytoplasm
   b. cell membrane
   c. nucleus
   d. ribosome
   e. vacuole
9. Which of the following does NOT describe genetic diseases?
   a. genetic diseases are caused by infectious agents
   b. genetic diseases are passed from parents to offspring
   c. genetic diseases can be caused by a single gene
   d. genetic diseases can remain latent for many years
10. Which of the following statements most accurately represents the relationship between chromosomes, DNA, and genes?
   a. DNA makes up chromosomes
   b. chromosomes make up genes
   c. genes make up DNA
   d. chromosomes make up DNA
11. What determines sex in human offspring?

a. 1 chromosome pair (the sex chromosomes)
b. 1 gene (the sex gene)
c. multiple genes throughout the genome (the sex determination complex)
d. mitochondrial DNA
e. sex determination is not genetic

12. Your muscle cells, nerve cells, and blood cells look different because each kind of cell
    a. contains different kinds of genes
    b. is located in different parts of the body
    c. activates different genes
    d. contains different numbers of genes
    e. has experienced different mutations
13. Which of the following groups do NOT possess DNA?
    a. animals
    b. bacteria
    c. fungi
    d. minerals
    e. plants

The presence of a facial freckles in humans is controlled by the expression of one gene with two alleles. The "freckle" allele is dominant to the "no freckle" allele. (Assume that dominance in this scenario refers to complete dominance.) Use this information to answer the questions 14 & 15.

14. Juan and Carolyn both have freckles, but their daughter Katie does not. What does this information indicate?
    a. One of the parents carries a "no freckle" allele
    b. Each of the parents carries a "no freckle" allele
    c. Neither of the parents carry a "no freckle" allele
    d. Katie carries at least 1 "freckle" allele
    e. There is not enough information provided to make a conclusion
15. If Juan and Carolyn have another child, what is the probability that the child will have freckles?
    a. 0%
    b. 25%
    c. 50%
    d. 75%
    e. 100%
16. Gene therapy would more likely be successful for conditions caused by
    a. a single chromosome
    b. a single gene
    c. environnemental influences
    d. multiple chromosomes
    e. multiple genes
17. The gene for human blood type possesses 3 alleles (A, B, & O). A and B are co-dominant with one another, and both A and B are dominant to O. If a woman has type AB blood and a man has type A blood, which of the following blood types could their children have?

a. A only
b. A or B only
c. A or AB only
d. A or B or AB only
e. A or B or AB or O

18. Which of the following is unique for every individual human (with the exception of identical twins)?
a. Chromosome number
b. DNA sequence
c. gene sequence
d. protein sequence
e. All of the above

19. Hemophilia is an x-linked recessive disorder in humans. If a couple, both of whom do not have hemophilia, have a son with the disease, what is the probability that their daughter would also have hemophilia?
a. 100%
b. 75%
c. 50%
d. 25%
e. 0%

20. Rank the following genetic structures in terms of size starting with the largest and proceeding to the smallest: chromosome, gene, genome, and nucleotide.
a. genome, chromosome, gene, nucleotide
b. genome, gene, chromosome, nucleotide
c. chromosome, genome, gene, nucleotide
d. chromosome, nucleotide, genome, gene
e. chromosome, nucleotide, gene, genome

21. Which of the following statements regarding human biology is MOST accurate?
a. The environment determines the expression of human traits.
b. Genes determine the expression of human traits.
c. Genes and the environment determine the expression of human traits.
d. Traits can be determined by the environment or genes, but not both.

Multiple Choice Answer Key (grade is out of 21)

1- B
2- E
3- C
4- D
5- D
6- C
7- B
8- C
9- A

10- A
11- A
12- A
13- D
14- B
15- D
16- B
17- D
18- B
19-E
20-A
21- C

First Short Answer Question (grade is out of 18)

Define each of the following terms:

1- Genome
2- Gene
3- DNA
4- Nucleus
5- Chromosome
6- Cell
7- Amino Acid
8- Protein
9- Living

First Question Answer Key (grade is out of 18)

1- Genome: The genetic material of an organism. It includes the genes and DNA sequences.
2- Gene: DNA fragment that codes for the synthesis of a specific peptide/trait.
3- DNA: Deoxyribonucleic acid. The carrier of genetic information that is the main constituent of chromosomes.
4- Nucleus: A membrane-enclosed organelle that is found in eukaryotic cells. A nucleus contains the cell's genetic material.
5- Chromosome: thread-like structures that are found within the nucleus of animal and plant cells. Chromosomes are made up of DNA sequences attached to histones (proteins).
6- Cell: The smallest self-contained part of an organism.
7- Amino Acid: The basic constituent or building block of a protein. The key elements of an amino acid include: carbon, hydrogen, oxygen, and nitrogen.
8- Protein: A macromolecule that is made up of one or more polypeptide chains. A protein is determined by its three dimensional structure and its specific sequence of amino acids.
9- Living: A condition that distinguishes organisms from dead or inorganic objects.

Second Short Answer Question (grade is out of 9)

Show the relationship between the following terms by explaining or drawing a concept map:

(a) Living, cells, and genes
(b) Genes, genome, and chromosome
(c) DNA, protein, and amino acid

Second Question Answer Key (grade is out of 9)

(a) All living things are made up of cells and the cell nucleus contains genes.
(b) An organism's genome is arranged into thread-like structures called chromosomes on which can be found individual genes
(c) DNA contains the code that determines the sequence of amino acids that are responsible for the formation of a specific protein.

Third Short Answer Question (grade is out of 7)

Read the following problem and answer its questions.

Mr. and Mrs. D are married and plan to have four children. They recently realized that each of them has a cousin with a blood disorder called β (beta) thalassemia major. Mr. and Mrs. D decide to visit their doctor in order to ask about this disorder. The doctor explains to these couple the following:

β thalassemia is a blood disorder that affects the hemoglobin in the red blood cells. This disorder is inherited; it passes from parents to their children in their genes. The allele responsible for beta thalassemia is recessive and is given the symbol β^o. If a child receives a copy of this recessive allele from both parents, then he/she will have the beta thalassemia major disorder. This child's genotype is $\beta^o\ \beta^o$. People who have the beta thalassemia major disorder usually have severe anemia and might die if left untreated. If a child receives one of the beta thalassemia alleles and another normal allele (β), then he/she will have beta thalassemia minor. This child's genotype is $\beta\ \beta^o$. This child will not have significant health problems. A person who has two normal alleles of this gene has a genotype of β β. Any person can be tested for thalassemia by doing a simple blood test.

Mr. and Mrs. D wanted to find out if their future children might have thalassemia. The doctor explained to these couple that if both parents have β thalassemia minor (genotype $\beta\ \beta^o$), then there is only one-in four chance of having a child with β thalassemia major (genotype $\beta^o\ \beta^o$) with an equal chance as well of having an unaffected child (genotype β β). There is also a chance that half of their children will have β thalassemia minor (genotype $\beta\ \beta^o$).

a- If Mr. and Mrs. D both have the β thalassemia trait and they have 4 children does this mean that one of their children will be affected, two will have β thalassemia minor, and one of the children will have β thalassemia major? Explain your answer. (2 points)
b- Mr. and Mrs. D decide to do the thalassemia blood test although they feel well. What will they be able to predict from the test results? (2 points)

c- Mrs. D's test results indicate that she doesn't have the thalassemia form of the gene. Mrs. D's cousin who has β thalassemia major decides to visit the couple for the weekend. The cousin is fine but is on treatment for this disease. Mrs. D is concerned that she might catch the disease. Do you think that she should be concerned? (1 point)

d- Mr. D discovers that he has β thalassemia minor. State the possible genotypes of his parents knowing that neither of his parents has β thalassemia major. (1 point)

e- What are the chances of Mr. and Mrs. D having a child with β thalassemia major? (1 point)

Third Question Answer Key (grade is out of 7)

(a)No, this is a simple prediction. The children might all come out normal, but it depends on the chance. There is a higher chance though that the children might get thalassemia, whether major or minor because only a quarter is normal. (2 points)

(b)The blood test results will allow the couple to predict if their children might have thalassemia major, minor, or none. (2 points)

(c) Mrs. D should not be worried, because thalassemia is a genetic disease which means that it is not infectious. (1 point)

(d) In order for Mrs. D to have thalassemia minor, one of his parents must have thalassemia minor. The other parent might also have thalassemia minor or might not carry the disease at all. (1 point)

(e) The chance is 0%. It is not possible at all in this case. (1 point)

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