AMERICAN UNIVERSITY OF BEIRUT

DESIGNING A TEACHER PORTAL BASED ON ARGUMENTATION BIOLOGY LESSONS FOR GRADE 10: INTEGRATING TOULMIN'S FRAMEWORK IN THE LEBANESE CURRICULUM

by
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ABSTRACT
OF THE THESIS OF

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Title: Designing A Teacher Portal Based on Argumentation Biology Lessons for Grade 10: Integrating Toulmin's Framework in The Lebanese Curriculum

This project aims to design six argumentative biology lessons for Grade 10 students grounded in Toulmin's Argumentation Framework or Model (TAM) for teaching biology and integrated with the Argumentation Model. Six lesson plans are selected from the Lebanese Grade 10 Biology curriculum and Toulmin's model is integrated into them. They are designed to engage students through student-centered teaching styles based on discussion and debate, group work, lab-based investigations, and report writing. The newly modified lesson plans foster scientific reasoning and encourage collaborative dialogue that deepens conceptual understanding through structured discussions and lab investigations, supported by evidence, while writing scientific essays. The designed lesson plans are customized to be easily adopted by teachers who will shift their teaching styles from teacher-centered strategies, such as lecturing to student-centered styles, such as argumentation. Like any innovation, this new integrated lesson plan may have limitations that require the cooperation of administrative vision and teachers' qualifications to overcome these disadvantages and turn them into strengths. The outcomes of these newly created lesson plans are successfully measured, practically explored, and can be physically applied in a real classroom setting

TABLE OF CONTENTS

ILLUSTRATIONS

Figure

TABLES

Table

ABBREVIATIONS

Toulmin's Argumentation Pattern…………………………………………. (TAP)

Toulmin's Argumentation Model ………………………………………….(TAM)

CHAPTER 1

INTRODUCTION

"Our basic aim is to make explicit the implicit structure of the arguments we use in practical reasoning." (Toulmin, 1958)

— Stephen Toulmin, The Uses of Argument (1958)
"Arguments, like men, often are pretenders"

— Plato (1871). *Phaedrus* (B. Jowett, Trans.). (Original work written ca. 370 BCE)

We often use the term "argument" to refer to the way we present our ideas and opinions. We think about debating, disputing opinions, or even fighting with someone we disagree with. But in this project, an argument is used to explain socio-scientific content that can be taught and communicated to build a scientific debate. Using inductive and deductive reasoning in arguments ensures that each claim is backed by clear, valid reasons. It aids us in building stronger mindsets, more persuasive scenarios, and spotting weaknesses in opposing views.

Effective communication in arguments ensures an efficient sequence of scientific ideas that are presented clearly and understood by all partners. Structured argumentation in scientific domains and teaching fosters students' critical thinking and their capabilities to evaluate content rigorously. By engaging in argumentation during Biology lessons, learning will become more active, collaborative, and confident in constructing and defending scientific explanations.

Teaching and learning science are a dialogic process that occur between teachers and students and are immersed in specific and complex contexts. This invites reflection on how to transform science lessons into an environment that gives relevance to the subjects, not only using students' life stories, mental models, and interests but also their ways of communicating and constructing science in class. It also highlights the importance of the intensive use of language or new communication modes. In other words, promoting debates and discussions in small groups is an effective means not only to achieve the co-construction of collective and more meaningful understandings but also to facilitate the construction of meaning of the concepts and thereby consciously transfer them to contexts outside the classroom (Osborne et al. 2015).

Proper argumentation in science classrooms promotes conceptual understanding of complex phenomena while also giving learners the ability to present evidence-based scientific ideas that support claims. Evidence for an idea being presented could be in support of or against a certain explanation that has been formed through observation, experimentation, and/or investigation. Being able to argue effectively requires the ability to communicate properly and reason to establish and prove why the gathered evidence confirms the claims being made. Clear reasoning in science involves the use of scientific ideas, theories, or principles to make logical connections that show evidence in support of the claims. This fundamental process is used every day to uncover truth and solve conflicts (Grumney, n.d.).

Students would benefit greatly if teachers taught them how to defend their way of thinking with evidence and reasoning while also staying open-minded to other ideas. Doing so would teach them how to converse and interact as professionals in science. Having the ability to participate in a conversation about the critique of scientific ideas, discoveries, phenomena, etc., allows students to reflect on their true understanding of the ideas while also helping them find gaps in their own reasoning and arguments. Accepting claims, ideas, or points blindly ignores the opportunity to practice critiquing ideas, creating claims, gathering evidence, and linking that evidence to make an argument. This methodical process, which is often skipped in science classrooms, gives students a chance to practice testing claims, refining their positions, and effectively communicating evidence-based ideas to their peers. These methods of investigation teach proper scientific reasoning and communication skills that will simultaneously promote higher-order student thinking—a critical mental process that is essential for true learning (Grumney, n.d.).

There is great significance in incorporating argumentation and the ability to engage in critique within the science curriculum. The discussion focused on the importance of giving students the opportunity to engage in argumentation and questioning, not only to help build their understanding in science but also to develop their ability to read scientifically. The need to encourage students to ask questions, critique others, gather evidence, and build arguments is crucial because it forces individuals to cognitively engage in defending their own positions. By doing this, they are practicing what real scientists do every day. The scientific skills and processes are the core of scientific practices themselves, and without them, there would be no construction of reliable knowledge (Grumney, n.d.).

The professional community of science educators collectively encourages teachers to give students the space and opportunity to create, innovate, and experiment with argumentation in the construction of scientific knowledge. All the research studies that investigated and implemented argumentation-based strategies in the classroom discovered that students could develop and improve their argumentation skills and understand the concepts by being involved in the production of spoken and written arguments (Grumney, n.d.).

Argumentation skills are used to analyze the information about a topic, and then the analysis results will be communicated. Thus, the use of argumentation in science learning is a part of improving higher-order thinking skills. The assessment of the quality of argumentation skills refers to Toulmin's Argumentation Pattern (TAP). TAP is an appropriate choice to measure someone's argumentation skills. Toulmin classifies six essential argumentation elements: claim, grounds, warrant, backing, qualification, and rebuttal. Characteristics of argumentation include: (1) the claim is the core of argumentation, (2) the ground is the evidence that supports the claim, (3) the warrant is the connector between the ground and the claim, (4) backing is the evidence that strengthens the warrant, (5) rebuttal is the exception or rejection, and finally (6) qualifiers or qualifications are the situations that contain certain possibilities in an argument (Pratiwi et al., 2023).

While teaching Biology lessons, instructors delve deeply and explore the scientific misconceptions in the students' understanding, which is crucial because it reveals the gap between their prior knowledge and the scientific explanations. When teaching is based on argumentation, it encourages students to express their ideas openly, defend their reasoning, and engage with counterarguments. This process brings misconceptions to the surface, allowing both the instructors and the learners to specifically and critically interpret scientific beliefs. Through sequenced and structured discussions, students are guided to reconstruct their understanding in line with scientific reasoning. Thus, argumentation not only helps identify misconceptions but also provides a powerful framework for enhancing their scientific conceptions through reflection, reasoning, and peer dialogue.

The Statement of The Problem

When teaching biology through argument, you are teaching students how to think critically and communicate their thoughts about the course material, while also teaching them how to express themselves in scientific writing. Whatever the argument is, what matters most is the presence of claims, reasoning, and evidence, just as in the real-world issues we encounter and seek to understand. The purpose of this project is to design and implement six argumentative biology lessons for Grade 10 students, grounded in Toulmin's Argumentation Framework and anchored in an Argumentation Model for teaching biology. This merging and design formulate a special student-centered lesson that fosters scientific reasoning and encourages collaborative dialogue, deepening conceptual understanding through structured discussions and lab-based investigations, all supported by evidence while writing scientific essays.

Previous studies have demonstrated the effectiveness of argumentation in enhancing students' engagement with scientific content and improving their understanding of socio-scientific issues (Osborne et al.). These studies emphasize that embedding argumentation into scientific instruction helps students construct and evaluate scientific claims, supporting the development of critical thinking and a deeper understanding of scientific concepts.

In the Lebanese educational context, similar challenges persist. Research by Yacoubian and BouJaoude (2010) highlights the gap between curricular goals and students' actual understanding of scientific concepts, attributing this to the lack of instructional resources and argumentation-focused teaching strategies. This project directly addresses the gap in the Lebanese curriculum by developing clear learning objectives, constructing evidence-based claims, and aligning content with students' cognitive levels, designed to ensure the lessons are successful, practical, and applicable in a real classroom setting.

By equipping teachers with scientifically designed lesson plans, they will be able to integrate argumentation both structurally and pedagogically. Moreover, the academic outcome will be efficient by fostering students' scientific literacy and self-efficacy. Furthermore, in a broader scope, if this argumentative teaching style is adopted by schools—vertically across levels and horizontally across scientific disciplines—it will contribute to a more reflective, inquiry-driven science education in the Lebanese curriculum.

In light of these anticipated benefits, this project is guided by the following research question: How can Toulmin's model be integrated into the Grade 10 curriculum in Lebanon?

The objective of this project is to integrate the lesson plans into a specific website (A teacher Portal)

The Purpose of the Report

This project is based on Toulmin's Argumentation Framework merged with the Argumentation Model of Teaching Biology, which is applied to the biology lessons in the Grade 10 governmental curriculum. Six newly developed argumentative lesson plans have been designed to engage students through student-centered teaching styles based on discussion and debate, group work, lab investigations, and report writing. These lesson plans aim to help teachers more effectively achieve their learning objectives and allow students to retrieve and apply information more effectively than those taught by traditional teacher-centered methods, such as lecturing. Grade 10 is specifically targeted in this report because it is an academic stage that doesn't involve the pressure of official governmental standardized examinations. Although these lesson plans are carefully designed and respect the students' abilities based on Grade 10 standards and levels, there may still be some limitations during their implementation.

One potential limitation is that the lesson plans are typically designed to cover all the stages of the Augmentation Model, which may be time-consuming compared to the allotted time given by the Ministry of Education subject coordinators. Another limitation is the variability of teachers' qualifications, which affects their effectiveness and experience in handling and managing time and the attitudes of the learners. Additionally, there may be limited awareness among teachers and administration about the value of incorporating argumentation into science education. Furthermore, financial and logistical obstacles may arise, especially if schools are not equipped to physically and safely support the biology lab requirements that will be carried out based on the Argumentative Model. Finally, the success of these lesson plans depends on the teachers' ability to understand and engage students, regardless of their ethnicity, cultural, or educational background variations, to motivate learners to communicate effectively with their peers.

The importance of this teaching style goes beyond Grade 10. It can be extended vertically across all grade levels, especially beginning from Grade 6, and horizontally across other subjects to support the development of critical thinking skills and enhance self-esteem, which are essential for empowering students in their future academic, professional, and personal lives.

CHAPTER 2

LITERATURE REVIEW

In this part of the study, a theoretical background about argumentation and literature reviews different studies that investigated argumentation and its effect on students' critical thinking skills, conceptual understanding, and argumentation skills will be introduced.

Argumentation as Part of Everyday Life

Argumentation can be implemented while speaking to friends, co-workers, and even with oneself in the process of making decisions. Argumentation plays a dominant role in the formation of explanations and theories by scientists, as they choose the evidence to relate to their claims using warrants and backings (Toulmin, 1958). Therefore, argumentation is an essential part of science education and should be taught explicitly as part of the inquiry in science classes (Jiménez-Aleixandre & Erduran, 2007; Erduran & Jiménez-Aleixandre, 2012; Kelly & Takao, 2002; Kitcher, 1998; Pera, 1994; Zohar & Nemet, 2002). In fact, research on argumentation in science education has grown significantly over the past few decades (Anderson, 2007).

Argumentation is defined as a type of discourse through which arguments can be individually and collaboratively built and evaluated in consideration of experimental or theoretical evidence, different opinions, reasoning, and rebuttals (Jiménez-Aleixandre & Erduran, 2007; Kuhn, 1993). It has been a chief instructional approach and goal for science education in many countries (Bell, 2004; Lee et al., 2009; Osborne et al., 2004a; Ozdem et al., 2011). Argumentation is an instructional approach that falls within the scope of social constructivism theory because knowledge in argumentation is produced through social interactions (Giri & Paily, 2020). Therefore, in this section, first, some information about social constructivism is provided.

2.1.1 Social Constructivism:

Social Constructivism is a theory of learning proposed by Lev Vygotsky. According to Vygotsky, learning is not separate from its social context and, in fact, happens through social interactions: Every function in the child's cultural development appears twice: first, on the social level and, later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals (Vygotsky, 1978, p. 57). Social constructivism is built on certain assumptions about reality, knowledge, and learning. Reality is not formed before social interactions (Kim, 2001).

Therefore, not individuals but group members create the characteristics of the group or the world (Kukla, 2000). Vygotsky stressed that language and culture constitute the models through which individuals communicate, have experiences, and make sense of the world around them. He claimed that knowledge is not merely constructed but co-constructed; and cognitive systems are socially framed ("Social Constructivism," n.d.).

Therefore, humans can fabricate meaning through interaction with other people and the environment in which they live (Amineh & Asl, 2015). Social constructivism portrays knowledge as socially constructed (Berger & Luckmann, 1966). According to Vygotsky, learning does not happen passively, cultivated by external causes or within a single human; rather, it is a social process and a collaborative course (McMahon, 1997). Social constructivists claim that humans learn through engagement in social interactions and collaboration (Amineh & Asl, 2015). According to Vygotsky (1978), higher-order thinking processes are derived from the use of language. In argumentation, students construct knowledge through participation in dialogical reasoning and relationships between individuals to resolve conflicts, share knowledge with other members of the community, and answer the questions set forth while backing up their responses with valid evidence. In such a context, learning happens through cognitive activities and social interactions (Baker, 1999; Venville & Dawson, 2010). Through argumentation, students construct knowledge claims individually and collaboratively while evaluating them in consideration of evidence (Jiménez-Aleixandre & Erduran, 2007). Thus, argumentation aligns with the epistemological assumptions of social constructivism, which is an important goal in science education (Hofstein et al., 2008). Many potential benefits are emphasized by science educators when argumentation is used in science education. One benefit is that the quality of science learning is enhanced because students are engaged in scientific reasoning publicly. This externalization of reasoning enables students to model the cognitive processes of an expert and recognize faults in their thoughts through interactions with other students and their instructors. Brown and Palincsar (1989) emphasize the importance of collaboration in providing frameworks for cognitive processes when students make their thinking processes and strategies public. These can then be modeled privately. When argumentation is practiced by students in the classroom, they participate in a community of learners (Mason, 1996) by making their reasoning public while backing their claims with evidence and evaluating different claims (Jiménez-Aleixandre & Erduran, 2007). As a result, students become more capable of developing rational reasoning about the natural world and transferring these reasoning skills to social areas (Bricker & Bell, 2008; Kuhn, 2010). This contribution of argumentation is grounded in situated cognition and accepts the learning context as communities of learners (Collins et al., 1989; Jiménez-Aleixandre & Erduran, 2007; Lave & Wenger, 1991). Additionally, students' critical thinking and communication skills are reinforced through argumentation in science classes, as they are asked to make their reasoning public, support their claims with valid evidence, and evaluate competing explanations for the same phenomenon. This dimension of argumentation stems from the sociocultural perspective and the theory of communicative action (Habermas, 1984; Jiménez-Aleixandre & Erduran, 2007; Wertsch, 1991). Scientific literacy is also supported through the use of argumentation since its application in science classes encourages students to learn how to speak and write in scientific language while attempting to persuade other community members (Kelly & Bazerman, 2003). This potential is derived from social semiotics and language studies (Jiménez-Aleixandre & Erduran, 2007; Kress et al., 2001; Norris & Phillips, 2003).

Moreover, argumentation also supports the adoption of the customary actions of scientific culture and epistemology for developing and evaluating knowledge, since students relate evidence to the claims and choose among the competing theories in argumentation. This potential benefit of argumentation is drawn from the epistemology of science (Jiménez-Aleixandre & Erduran, 2007; Leach et al., 2003; Sandoval, 2005).

Argument vs. Argumentation

Merriam-Webster (n.d.) defines an argument as "a coherent series of reasons, statements, or facts intended to support or establish a point of view." An argument could be both individual, formed of an inner set of linked reasoning, and social, formed of different viewpoints between people (Kuhn, 1993). Kuhn (1993) points out that the two are interrelated, as social argumentation has the power to develop internal argumentation. Van Eemeren and Grootendorst (2004), on the other hand, do not agree with the double meaning of the argument and limit the meaning to the social side. Both sides could be accepted if the argument stands for the product of reasoned discourse, whereas argumentation stands for the social discourse (Jiménez-Aleixandre & Erduran, 2007; Kuhn & Udell, 2003).

This shows that arguments and argumentation are different. Osborne et al. (2004) regarded argument as the signification of claims, data, backings, and warrants that make up the content, whereas argumentation is the signification of the process. There are different definitions of argumentation. The dictionary definition of argumentation is: "the act or process of forming reasons and of drawing conclusions and applying them to a case in discussion" (Merriam-Webster, n.d.). Duschl et al. (2007) define argumentation as a "logical discourse whose goal is to tease out the relationship between ideas and evidence" (p. 33). On the other hand, van Eemeren et al. (1996) define argumentation as "a verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a controversial standpoint for the listener or reader by putting forward a constellation of propositions intended to justify (or refute) the standpoint before a rational judge."

Arguments are approached differently in literature. One approach views argument as (1) rhetorical (Kuhn, 1991), (2) didactic (Boulter & Gilbert, 1995), and (3) dialogical or multi-voiced (Driver et al., 2000).

(1) From the rhetorical or didactic perspective, the purpose of the argument is to convince someone of the truth of a case. Therefore, the rhetorical argument is one-sided. This is commonly used in science classes where teachers explain scientific

explanations to the students and try to make them see that these explanations are reasonable.

(2) In the dialogical or multi-voiced argument, the argument is constructed through consideration of different perspectives, and the goal is to arrive at a consensus. The dialogical arguments can happen individually or socially (Driver et al., 2000).

(3) In another approach by van Eemeren et al. (1996), the argument has three types: analytical, rhetorical, and dialectical. The analytical argument is structured through formal logic in which the conclusion stems directly out of the premises deductively or inductively. Such arguments could be material implication, deduction, fallacies, and syllogism (Jiménez-Aleixandre et al., 2000). This, however, is not sufficient to define the discourse of producing arguments in making science (Walton, 1999). The rhetorical and dialectical arguments are structured in informal reasoning and can be in either individualistic or social forms.

(4) Monologues take place with the purpose of convincing an audience in rhetorical arguments, whereas dialogues between two or more people happen to resolve a dispute in dialectical arguments (Kolsto & Ratcliffe, 2008).

Knowledge and persuasion are the stressed features of rhetorical arguments, which are oratorical in nature. Debates and discussions with reasoning that include premises, which are not evidently accepted, involve dialectical arguments (Jiménez-Aleixandre et al., 2000). Research into the argumentation schemes applied by the students shows that the students in real life use a combination of analytical, rhetorical, and dialectical arguments (Duschl, 2008).

2.1.3 Theories of Argumentation

The systematic conclusions of the discourse on argumentation are referred to as argumentation theory. One end of the theories of argumentation adopts a rationalistic view, which has its roots in the philosophical perspectives of the Eleatics and Plato. In the rationalistic view of argumentation, knowledge is deduced through reasoning based solely on facts. There is no social aspect to argumentation in this view. Another perspective on argumentation is interpretivism. In this view, a phenomenon can have multiple truths depending on subjective features, such as individual experiences and interpretations of these experiences (Puvirajah, 2007). However, well-known definitions of argumentation, such as Toulmin's argumentation pattern (1958), Perelman and Olbrechts-Tyteca's argumentation of point of departure (1969), and Walton's argumentation of presumptive reasoning (1996), fall between these two extremes (Puvirajah, 2007). The seven main theories of argumentation are explained in this section. These are Aristotle's theory of argumentation, Toulmin's (1958) model of argumentation, Perelman and Olbrechts-Tyteca's (1972) argumentation of point of departure, Johnson and Blair's (1977) informal logic, Ducrot and Anscombe's (1986) theory of radical argumentation, Walton's (1996) argumentation of presumptive reasoning, and Lawson's (2003) Hypothetical-Predictive Argumentation.

Aristotle's (384 – 322 B. C.) Theory of Argumentation:

Aristotle, with his proposal of three types of arguments—analytic, dialectic, and rhetorical—opened the pathway to argumentation. The analytic argument is based solely on facts and excludes the verbal and situational pragmatic elements that affect the process and product of the discourse on argumentation. For this reason, the analytic argument is said to be completely objective and hence falls within the rationalistic paradigm (Allen, 2007). Mathematical proof serves as a good representative of the analytic argument since different experts in the field will arrive at the same result when they work on the same problem (Puvirajah, 2007).

Dialectic involves a paradoxical course between opposing views (Maybee, 2020). Therefore, dialectic argument is the logical discussion of a thesis and antithesis through dialogue to synthesize a new thesis. Socrates and Plato are the founders of the dialectic argument, which includes thesis and antithesis, but Hegel introduced the third component, synthesis. Dialectic arguments can be employed to resolve disagreements, as the two opposing parties (thesis and antithesis) discuss their viewpoints to arrive at a solution (synthesis) accepted by both parties (Puvirajah, 2007). The rhetorical argument involves attempts to persuade someone to agree with a particular standpoint. Therefore, convincing the audience plays an important role here. The arguer employs any evidence that may be relevant and even appeals to the emotions of the listeners to make their point valid and to persuade others. This type of argument is especially used in judicial contexts (Puvirajah, 2007).

Toulmin's (1958) Model of Argumentation:

From Aristotle's three types of argument until the late 19th century, analytic argument, which is also referred to as formal logic, was dominant during argumentation. Dialectic and rhetorical arguments gradually came forth and started to challenge the superiority of formal logic in the argumentation arena.

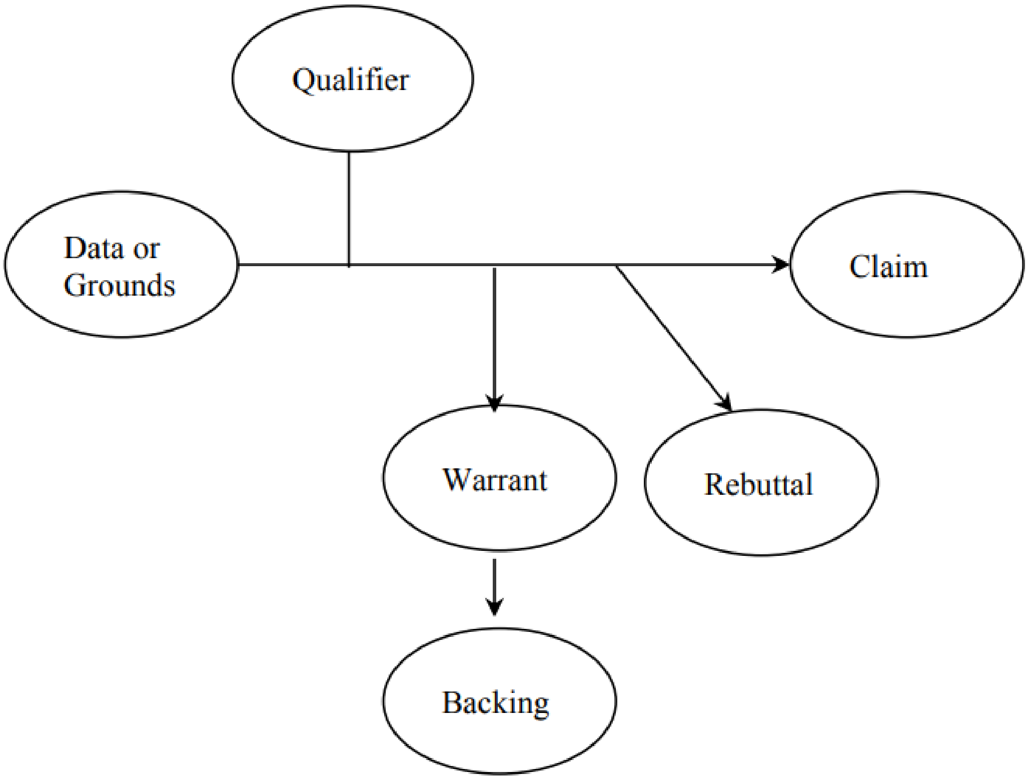
Toulmin (1958) and Perelman and Olbrechts-Tyteca (1972) became the most influential pioneers of this challenge. Toulmin's model of argumentation became the foundation upon which other models rested. Toulmin defines how argumentation happens naturally in everyday life and names this kind of argument as a substantial or practical argument. Analytic arguments include claims that are only supported by universal facts. However, it is not always easy to find universal principles to support the claims in every situation in today's world. A claim found valid in social sciences may not be accepted as valid in natural sciences. Toulmin disagreed with having universal principles used to support the claims and took the view of rationality in which the claims are supported by the type of evidence depending on the context. Therefore, his idea of practical argument falls in between universality and relativism (Foss et al., 2001; Puvirajah, 2007).

Toulmin (1958) describes argumentation as a discursive process in which claims are based on the evidence reached through the usage of warrants and backings. Toulmin studied arguments in various contexts, including the arguments in science and legal settings, and suggested an argumentation model with the constitutive elements.

According to Toulmin (1958), a qualified argument is formed of six parts (Figure 2.1): grounds or data, claim, warrants, qualifiers, rebuttals, and backing. The grounds or data are the evidence used to prove the argument; the claim is a statement being argued for general acceptance; warrants are the general statements that link the grounds and the claim; backings are used to strengthen the warrants; rebuttals are the exceptional situations under which the argument is not valid. Arguments become more persuasive when the arguer himself states the rebuttals rather than being mentioned by someone else in the audience (Puvirajah, 2007). Toulmin also brings qualifiers to his model as statements that identify the circumstances under which the argument is supported. The qualifiers could be words like, "possible, likely, probable, usually, generally," etc., which are the representatives of non-absolutism (Puvirajah, 2007). Qualifiers bring strength to the argument and hence, make the argument more persuasive. Most of the people, especially the educated ones, tend to acknowledge non-absolute positions rather than agreeing with the absolute standpoints (Wangerin, 1993).

Figure 1

Toulmin's Argumentation Frame 1



Data, claims, and warrants are the primary components of all argumentations, and they might sometimes be the only components in simple argumentations. These three elements are required to make an argument valid. However, all six elements of Toulmin's model are required to make an argument a persuasive one (Puvirajah, 2007). All these six parts in the model are interconnected and constitute Toulmin's argumentation theory, which is also known as Toulmin's Argument Pattern (TAP) (Erduran et al., 2004). Although all six elements are necessary for a good argument, rebuttals are the most important component of any qualified argument. This is because of the reason that rebuttals yield opportunities for testing the validity of the argument that is put forward. For that reason, no change in the viewpoints of the participants takes place without having the rebuttals in the arguments. This is why rebuttals are very important elements of qualified arguments (Erduran et al., 2004). Toulmin differentiates practical argumentation from formal logic. In formal logic, using inference from the evidence through reasoning makes claims. This means that the claims are the end product reached through inference. In practical argumentation, on the other hand, claims, after being proposed, are justified by giving reasons, and the justification used is field-dependent (Puvirajah, 2007). According to Foss et al. (2001), justification is a retrospective process whereas inference is a prospective process. In practical argumentation, the justification of the argument is more important than the contribution to the conclusion. Therefore, in TAP, an argument is valid when its justification is a logical one, in other words, when the justification is related to the data, warrants, backings, rebuttals, and qualifiers. According to Toulmin (1958), definitions of the elements of arguments, which are claim, data, warrants, backings, qualifiers, and rebuttals are the same, and hence, field-invariant. However, what is included inside the data, backing, or warrant, differs from one subject area to another, and hence, is field-dependent. Arguments, in practice, however, are dependent on the field because of the fact that the values of the field and its guiding conceptions shape the warrants and backings, which form the claims (Osborne et al., 2004a). The implementation of Toulmin's framework for explaining the students' arguments, on the other hand, has some setbacks. The main issue in the implementation is the confusion that might be experienced in identifying what counts as claim, data, warrant, and backings in the students' arguments (Erduran et al., 2004; Sampson & Clark, 2008).

In addition, determining what counts as the data, a claim, or warrant is affected by the researcher's individual perspectives (Sampson & Clark, 2008). Moreover, the quality of an argument is defined according to the presence or absence of these components mentioned above in Toulmin's framework. Therefore, Toulmin's framework does not consider the accuracy of the data, warrants, and backings other than their presence or absence in an argument (Sampson & Clark, 2008).

Toulmin also agreed with this, that evaluations about the accuracy of an argument require the involvement of the subject knowledge in the arguments under question. The elements in Toulmin's model are also regarded as very general and broad in definition, and hence, the necessary levels of detail to support the reasons for an argument conveyed are not unclear (Duschl, 2008). Another limitation is that Toulmin's model does not take the linguistic and situational contexts into consideration.

Argumentation in real life and the making of science, on the other hand, are affected by these factors and hence, these factors should also be considered when the arguments are examined (Driver et al., 2000). Finally, the illustrations and graphics are assumed to be in addition to an argument in his model. They are, however, accepted as the main communicative elements of arguments in today's world (Driver et al., 2000).

In spite of these issues, this definition of argumentation by Toulmin has been widely used as a methodological and heuristic tool to analyze and assess the students' arguments in different domains, including history, English, and science (Bell & Linn, 2000; Dawson & Carson, 2020; Erduran, 2019; Erduran et al., 2004; Grimes et al., 2019; Jiménez-Aleixandre et al., 2000; Hart, 1998; Koomen et al., 2018; Mitchell, 1996; Pontecorvo & Girardet, 1993; Sampson & Clark, 2008; Zohar & Nemet, 2002). This model is still influential in various fields. The reason for this is the flexibility of

TAP since it can be applied to both field-invariant and field-dependent contexts. Therefore, it brings the beneficial factor of comprehension of students' arguments in different fields (Jiménez-Aleixandre & Erduran, 2007). Because of these reasons mentioned here, this study will also use TAP in creating the lesson plans for the electrochemistry topic and also in analyzing the students' arguments.

Perelman and Olbrechts-Tyteca's (1969) Argumentation of Point of Departure:

Perelman and Olbrechts-Tyteca (1969), in their book named La Nouvelle Rhétorique (1958, translated as The New Rhetoric, 1969), proposed an argumentation theory by excluding the absolutes of positivism and relativism. In their book they stated, "since argumentation aims at securing the adherence of those to whom it is addressed, it is, in its entirety, relative to the audience to be influenced" (Perelman & Olbrechts-Tyteca, 1969, p. 19). This statement shows that the important element of argumentation is the audience. In this theory, an argument is a sound one if it creates the desired effect on the audience. Therefore, the argument should be unique to its audience, which can be a particular one or a universal one (van Eemeren & Grootendorst, 1995). According to Perelman and Olbrechts-Tyteca, if arguments start with agreement points (e.g., facts, values), they can then reach the point where strong disagreement happens, and this stage is called the point of departure. After this point, it is important for the arguer that he makes his point a credible one for the audience. The ways to make the argument credible are bound to more than 100 techniques (argumentation based on the structure of reality, quasi-logical argumentation, argumentation to establish the structure of reality, etc.), which can create points of departure in the creation of the arguments (van Eemeren et al., 1996). One of the downsides of Perelman and Olbrechts-Tyteca's model is that many of these argument schemes are not explicit or overlap each other. Another downside is that Perelman and Olbrechts-Tyteca neglected the linguistic and contextual sides of arguments while mainly focusing on the isolated arguments. For that reason, it can be concluded that Perelman and Olbrechts-Tyteca's approach to argumentation was not different from the formal logic (van Eemeren et al., 2002).

Johnson and Blair's Informal Logic (1977):

Toulmin's, and Perelman and Olbrechts-Tyteca's theories were found to be formal and not applicable in everyday life. Informal logic, which is another philosophical approach to argumentation, was developed in the 1970s to investigate the premises and conclusions used in reasoning in everyday life and in a formal inquiry (Groarke, 2007). Johnson and Blair (1977), who are the pioneers of informal logic proposed three essential features for the premises to meet in an argument. These are relevance, sufficiency, and acceptability. A premise will be relevant if the actuality of the conclusion is dependent on it. The premise has to make ample evidence available for the conclusion in order to be called sufficient. Finally, the premises have acceptability if it is true or reliable (Damer, 2005). One downside of this informal logic theory is that how argumentation is evaluated was the only focus (van Eemeren, 2002).

Ducrot and Anscombre's Theory of Radical Argumentativism (1986):

After the shift to informal logic, Ducrot and Anscombre brought the approach of viewing the everyday language as a way of argument and named this approach Radical Argumentativism (Meyer, 1998). This was a linguistically oriented approach to the discourse of argumentation. According to Ducrot and Anscombre, any speech including still, even, but at least, etc. (these are called argumentative connectors) and almost, no less, only, very, etc. (these are called argumentation direction) have the power of forming a specific argument and a direction to the speech because of triggering some topos (van Eemeren & Grootendorst, 2004). For instance, there is a difference in argumentativeness of the phrases “it is ten o’clock” and “it is still ten o’clock.” Ductrot and Anscrombre’s approach to the argumentation as being the feature of everyday language, however, was not generally agreed on. The purpose was mainly to describe the syntactic and semantic features of argumentation. Therefore, the norms and criteria to develop and evaluate an argument were not the purpose of the theory (van Eemeren & Grootendorst, 2004).

Walton’s (1996) Argumentation of Presumptive Reasoning:

Walton (1996) introduced presumptive reasoning, which he defined as “neither deductive nor inductive in nature, but represents a third distinct type …, an inherently tentative kind of reasoning subject to defeat by the special circumstances (not defined inductively or statistically) of a particular case” (Walton, 1996, p. 43). In this theory, presumptions are the main argumentation contexts in everyday life settings (Rapanta, 2022). According to Blair (2001), presumptions “come into play in the absence of firm evidence or knowledge, which is why they are typically found in practical reasoning” (p. 366). A great portion of everyday communication includes fallacious arguments because of having an inaccurate element in its logic (Hamblin, 1970). According to Walton (1996), some of these fallacious arguments have the capacity of being presumptive in nature if the premise of the conclusion was not proven to be true or untrue. Therefore, he called such arguments as presumptive arguments in which the premise is acknowledged on condition in order to proceed in the argumentation process. In a presumptive argument, the conclusion is the tentative one dependent on the new information that might be encountered as one proceeds in the process of data or evidence collection (Walton, 1999). However, the new evidence may end up with the discard of the argument or provide more reasons to accept the argument that was put forward previously. An argument that is constructed in such a way has a dynamic nature (Walton, 2001). Presumptive reasoning takes place throughout the course of the exchanges of views in argumentation. Examples of such argumentation in school settings will be the laboratory investigations done in small groups (Jiménez-Aleixandre et al., 2000). Moreover, Walton theorizes that an argument will be valid depending on its dialogue contexts like the dialogue type, level of the discussion, and the commitments of the participants in the discussion, and some other factors that might be particular to the case of the argumentation (Walton, 1999).

In addition, Walton (1996) cultivated an argumentation schemes approach to argumentation and characterized 25 argumentation schemes. Walton et al. (2008) used 60 argumentation schemes and defined argumentation schemes as "forms of argument (structures of inference) that represent structures of common types of arguments used in everyday discourse, as well as in special contexts like those of legal argumentation and scientific argumentation" (p. 1). Each argumentation scheme has its own critical questions, which are tools for the respondents to advance the argument. However, what drives these questions, how the decision is made on choosing the right questions, or when the list of these questions is finished were not discussed by Walton (Blair, 2001).

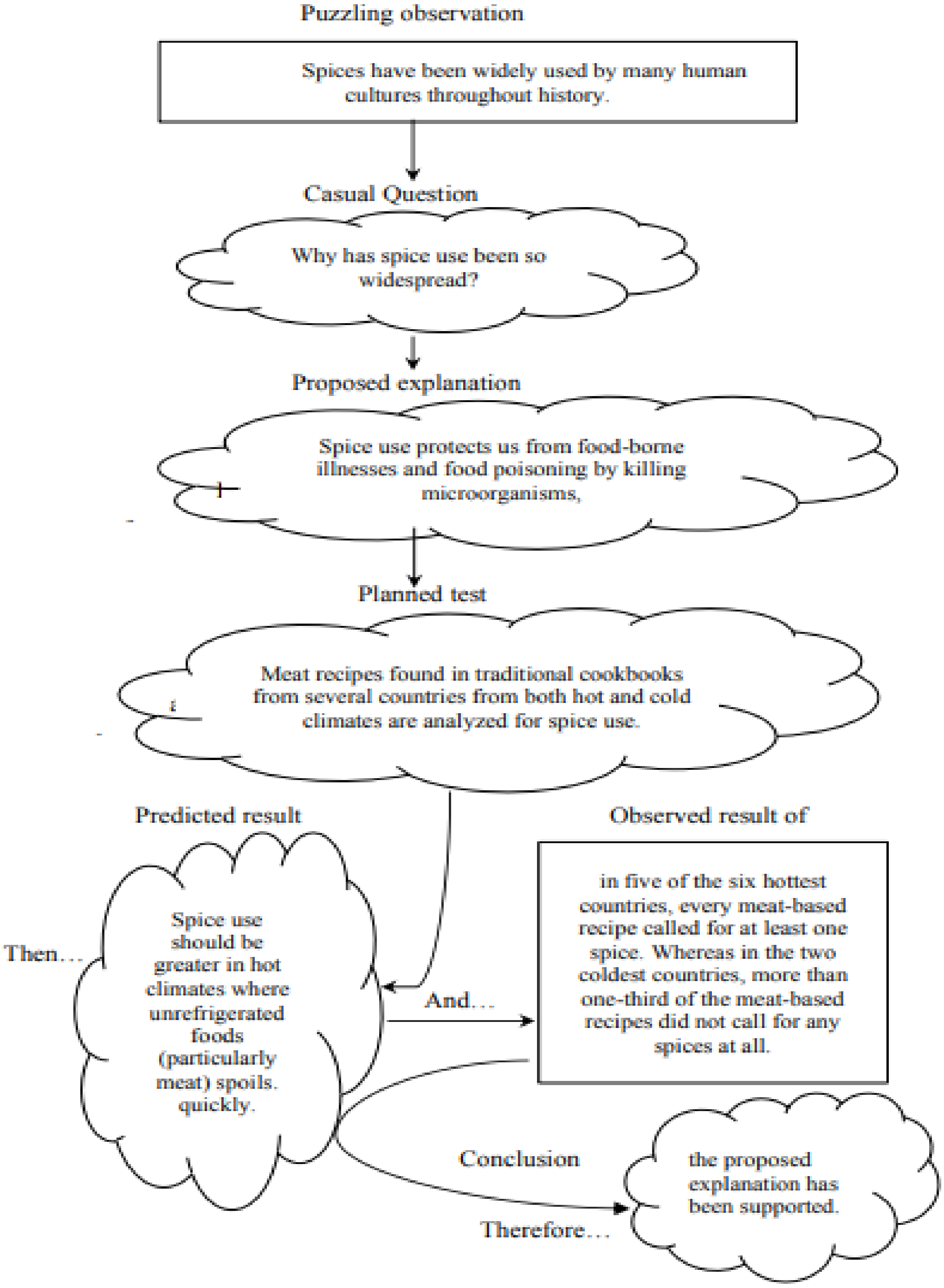
Lawson's (2003) Hypothetical-Predictive Argumentation:

According to Lawson (2003), the goal of argumentation is " to discover which of two or more proposed alternative explanations (claims) for a puzzling observation is correct and which of the alternatives are incorrect" (p. 1389). This process needs to develop an argument that may be true but also designs tests led by specific predictions and analysis of evidence (Sampson & Clark, 2008).

Lawson (2003) refers to this "a hypothetical-predictive argument" and postulates that this is more persuasive than arguments whose validity is tested by the presence of warrants, evidence, and backings. His argumentation (Figure 2.2) starts with a perplexing observation, which arouses questions to solve the perplexing side of the observation and is followed by a proposal of a possible answer to the question. This answer is then investigated by assuming that it is a valid answer, and results are put together to form the evidence. The evidence is then compared with the proposed answer for testing the validity of the answer. At this point, the initial answer could be accepted to be correct or discarded, and a new explanation of the perplexing observation could be produced as well. The linking words, which are "if/and/then," are used to link the explanation with the proposed test and prediction. When the sound explanation is claimed at the end, another cycle of argumentation starts to persuade or show that this explanation is correct (Lawson, 2003). Scientists form and examine their alternative explanations through the hypothetical-predictive argumentation (Sampson & Clark, 2008). The discourse involves reflective thinking and hence, requires some time. For that reason, this type of argumentation is especially used while having the conceptual change and construction of conceptual knowledge, which is the characteristic of declarative knowledge. Consequently, when the students in science classes construct hypothetical-predictive arguments with the required time spared, students' conceptual understanding and argumentative skills become improved (Lawson, 2003). When the model is inspected closely, however, it looks like the traditional scientific method rather than a model for the analysis of scientific argumentation. In addition, the model also lacks the scientific evaluation of the propositions made by the students (Puvirajah, 2007). Furthermore, the model has very specific applicability in terms of scientific disciplines and contexts (Sampson & Clark, 2008). With the introduction of informal logic and the new approaches to it, modern rhetoric argumentation took the form of being audience-centered while being communicated in everyday language and having a plausible premise conclusion relationship. The modern dialectic argument was viewed as finding a solution to disagreement by discussing the reasonableness of different standpoints. In the modern analytic view, the main concern is the thorough examination of the argument by using the instruments of linguistics, science, and mathematics. These modern approaches to argumentation, on the other hand, extend into each other (Reboul, 1990; van Eemeren, 2002). Science involves the use of all these three types of argumentations (Pera, 1994) but the use of dialectic and rhetoric argumentations is more dominant (Latour & Woolgar, 1986; Longino, 1990).

Figure 2

Hypothetical- Predictive Argumentative Model (Lawson,2003)



CHAPTER 3

METHODOLOGY

Understanding how to cultivate students' reasoning and argumentation skills is essential for developing critical and reflective thinkers. In Lebanon, the traditional Grade 10 curriculum often emphasizes factual recall over analytical discussion, highlighting the need for innovative instructional approaches that promote deeper learning. To address this educational gap, this study explores the potential of integrating Toulmin's Model of Argumentation within the Lebanese Grade 10 curriculum.

The guiding question for this research is:

How can Toulmin's model be integrated into the Lebanese Grade 10 curriculum?

The objective of this project is to integrate the lesson plans into a specific website (A teacher Portal)

This chapter outlines the research methodology adopted to investigate this question. It presents the research design, participants, instruments, procedures, and data analysis techniques used to examine how Toulmin's framework can be effectively embedded into the existing curriculum to enhance students' reasoning and argumentation skills.

For the methodology of this project, we will refer to the Argumentation Model and Toulmin's Argumentation Framework to design six Biology lesson plans selected from the Lebanese Curriculum of the Grade 10 Biology Book. The newly modified lesson plans differ from traditional lesson plans based on the 5E or inquiry approaches, as they place a greater emphasis on argumentation and debate among students, as well as between students and teachers.

Toulmin's model of argument has been used by researchers as a theoretical perspective on argument and as a methodological tool for analyzing sessions of scientific argumentation in high school academics. An adaptation of Toulmin's Argument Pattern (TAP) has also informed a professional development program for teachers. Research on the impact of the program on pedagogical practice shows that Toulmin-based materials are advantageous in helping teachers conceptualize arguments and model them for students. A framework developed from TAP can also be used to evaluate student outcomes when using argumentation rubrics (Simon, 2008).

In recent years, several studies in science education have focused on the analysis of argumentation discourse in classroom contexts and the importance of argumentation in the development of scientific knowledge and understanding. One implication that can be drawn from these and other studies, particularly the research of Kuhn (1991), is that argumentation is a form of discourse that needs to be appropriated by children and explicitly taught through suitable instruction, task structuring, and modeling. To this end, frameworks for conceptualizing arguments and communicating their meaning become important research tools and pedagogical devices.

Research on argumentation in science education has been underpinned by philosophical and cognitive perspectives on the role of argument. From a philosophical perspective, science involves the construction of theories that provide explanations for phenomena that are open to challenge and objection; science proceeds through dispute, conflict, and argumentation (Simon, 2008). Arguments about the interpretation of evidence and the validity of knowledge claims are central to science and scientific discourse.

From a cognitive perspective, argument is an important feature of reasoning and thinking. As students engage in argumentation, they learn to appreciate the connection between evidence and claim and the importance of justification in scientific arguments. From these different perspectives, researchers studying the quality of argumentation have developed theoretical and methodological frameworks for the conception and analysis of argumentation in science.

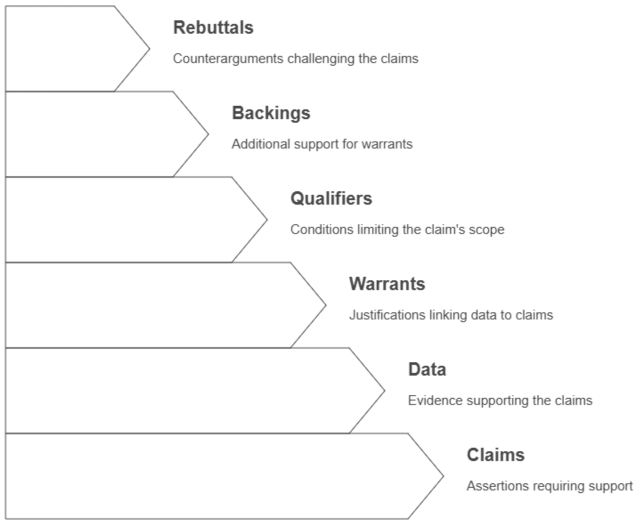
Among these is a framework derived from a model developed by Toulmin (1958), which offers the basis for a theoretical perspective on argument. Toulmin's Argument Pattern (TAP) illustrates an interconnection between argument components that facilitates a conceptualization of the meaning of argument.

History of Toulmin's Argumentation Model (TAM)

TAM is a structured framework or schema for the analysis of arguments. It was developed in 1950 by the philosopher Stephen Toulmin as an alternative to prevailing models and techniques of logical analysis. The schema was based on a jurisprudential analogy, loosely derived from the process of argumentation typically occurring in the courtroom. This typically involves contention being scrutinized and challenged on various grounds. Finally, the contentions are accepted or rejected on the merits of the various reasons offered pro or con, as perceived by a larger group of observers, all within a certain framework of accepted rules and practices of operation. These features in recognizable forms are very evident in TAM. The basic features of the scheme are listed below, with additional details and a diagram to express tangibly its importance (Chaudhuri, 1990).

Figure 3

Toulmin's Argumentative Model



Philosopher S. Toulmin based his method of argumentation on a model of law in which (1) a person makes a claim, then (2) gives grounds (data) to support that claim and (3) backs the grounds with a warrant. These three elements—claims, grounds, and warrant—are present in every argument. Three additional non-fundamental elements of Toulmin's model include backing, rebuttal, and qualifiers that may be added as necessary, but the primary fundamental elements consist of the claim, its grounds, and its warranty (Toulmin, 1958).

First, the claim, the basic purpose of an argument, can be an assertion, standard, or thesis. Next, the grounds, the foundation of the argument, are the evidence or specific facts that support the claim. Finally, the warrant—implied or stated—links the grounds to the claim and gives the grounds general support. These first three elements are essential to any argument. Qualifiers, when present, are sometimes used in the wording of the claim and are therefore different from the rebuttal and backing, which are often only implied. The backing establishes the reliability and relevance of the warrant, the rebuttal acknowledges exceptions that might invalidate the claims, and the qualifier modifies the claim (Karbach, 1987).

Detailed Elements of Toulmin's Model

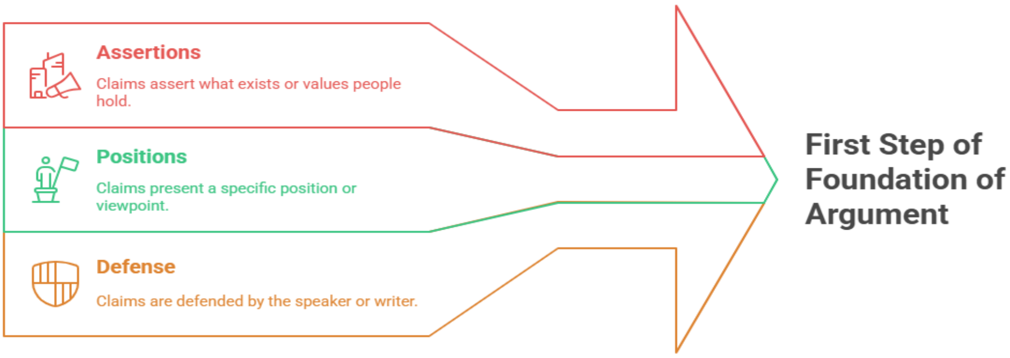
A. Fundamental Elements

Claims:

A claim is the assertion that authors would like to prove to their audience. It is, in other words, the main argument. It is a thesis, assertion, or proposition. It answers the question: "What do I want to prove?"

Figure 4

Types of Claims

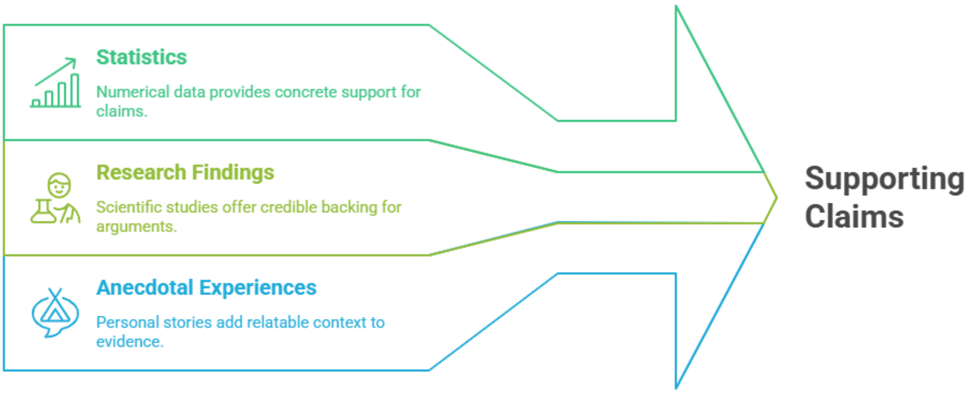


Ground:

The grounds or data of an argument are the evidence and facts that help support the claim. They are evidence in support of the claim. Answers: "What do I have to go on?" (Purdue Online Writing Lab, n.d.)

Figure 5

Forms of Data or Grounds



Warrant:

The warrant, which is either implied or stated explicitly, is the assumption that links the grounds to the claim. It supports the connection between the grounds and the claim. Answers: "How do I get from evidence to claim?" (Purdue Online Writing Lab, n.d.)

Figure 6

Warrant in Argumentation

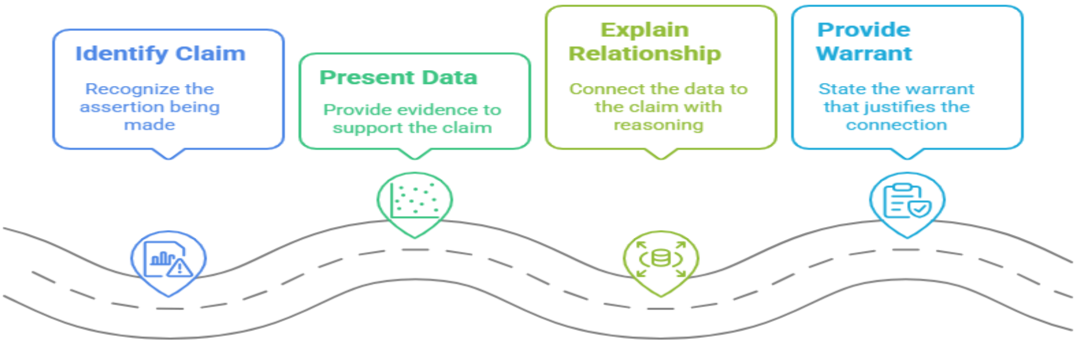


Figure 7

Argumentation Structure Pyramid- The first Fundemental Components: Claim, Warrant and Grounds

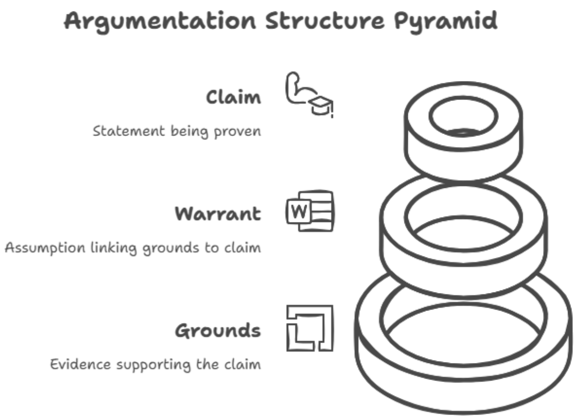


Figure 8

An Illustration that Describes how the Ground and the Warrant are important to obtain the Claim

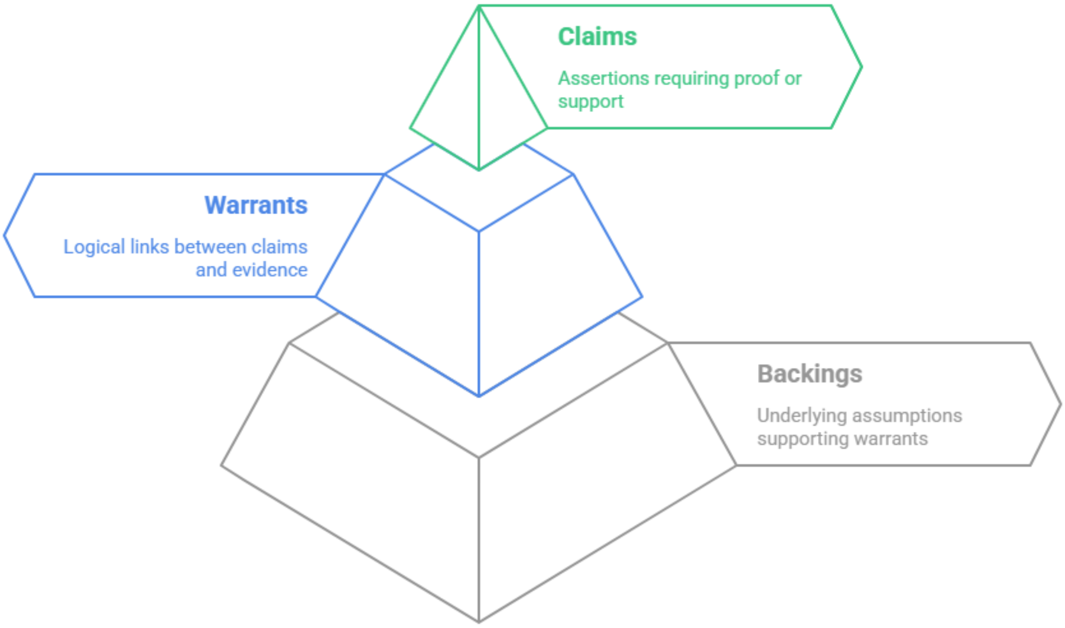
Non-Fundamental Elements

Backing:

The backing refers to any additional support for the warrant. In many cases, the warrant is implied, and therefore the backing provides support for the warrant by giving a specific example that justifies it. It supports the reliability of the warrant. Answers: "Is the move from grounds to claim safe and reliable?" (Purdue Online Writing Lab, n.d.)

Figure 9

Importance of Backing in Supporting Argumentation



Rebuttal:

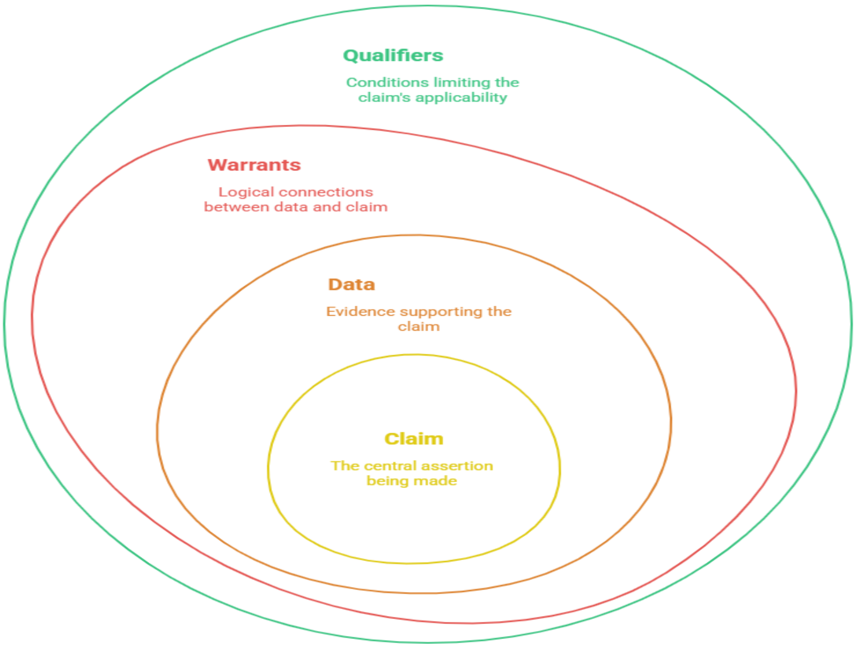
The rebuttal is an acknowledgment of another valid view of the situation. It is a fact, exception, or proposition that may invalidate the claim. Answers: "What possibilities might disrupt the argument?" (Purdue Online Writing Lab, n.d.)

Qualifiers:

The qualifier shows that a claim may not be true in all circumstances. Words like "presumably," "some," and "many" help your audience understand that you know there are instances where your claim may not be correct. The Qualifier: a qualification to hedge the argument based on the rebuttal. Answers: "Is a qualification necessary?" (Purdue Online Writing Lab, n.d.)

Figure 10

Structure of Argumentation



Rationale for Using Toulmin's Model

Toulmin's Model provides educators with many advantages for both constructing and analyzing arguments. It provides a clear and systematic framework that helps individuals develop, revise, and strengthen their own arguments by identifying essential elements such as the claim, data, and warrant. Additionally, it serves as an effective tool for evaluating the strength and structure of others' arguments, making it valuable in academic, scientific, and policy discussions. One of the notable benefits of using the Toulmin Model is that it often reveals gaps or weaknesses and limitations in analyzing, thereby encouraging deeper analysis and the development of additional supporting arguments or rebuttals. For instance, addressing a rebuttal within Toulmin's Framework may require constructing an entirely new argument, which fosters critical thinking and encourages consideration of contextual and socio-historical factors in argumentation.

Generate an Argument Instructional Model

This instructional model is designed to provide an opportunity for small groups of students to develop a claim that answers a research question based on an available data set. As part of this process, groups create a tentative argument that provides this claim and evidence that supports it, using a medium that can be viewed by others.

Each group then has an opportunity to share their ideas during an argumentation session. These sessions are designed to create a need for students to discuss the validity or acceptability of the various arguments based on the available information. Based on the outcomes of these discussions, students refine their claims to better explain or describe the phenomenon under investigation. Each student is required to write and submit a final argument to his or her teacher for the purpose of assessment. To conclude the activity, the teacher leads a whole-class reflective discussion and encourages students to consider what they learned about the content and the nature of science.

This model consists of five stages (Sampson & Schleigh, 2016):

- Stage 1: The Identification of a Problem and the Research Question
- Stage 2: The Generation of a Tentative Argument
- Stage 3: The Argumentation Session
- Stage 4: A Reflective Discussion
- Stage 5: The Production of a Final Written Argument

Project Methodology

The integration of scientific argumentation into the teaching and learning of biology can be difficult for both teachers and students. In fact, teachers often ask for specific instructional strategies and engaging activities based on these instructional activities that would allow students to learn how to engage in scientific argumentation as part of the inquiry process.

In this project, six lesson plans are selected based on their sociocultural content from the Grade 10 Biology Lebanese curriculum, and designed based on argumentation using Toulmin's Argumentative Model (TAM) according to the stages of the argumentation that are listed above.

Figure 11

The Diagram Illustrates The Merging Of The Stages (Stages 1 And 2) Of Argumentative Model With Toulmin's Framework

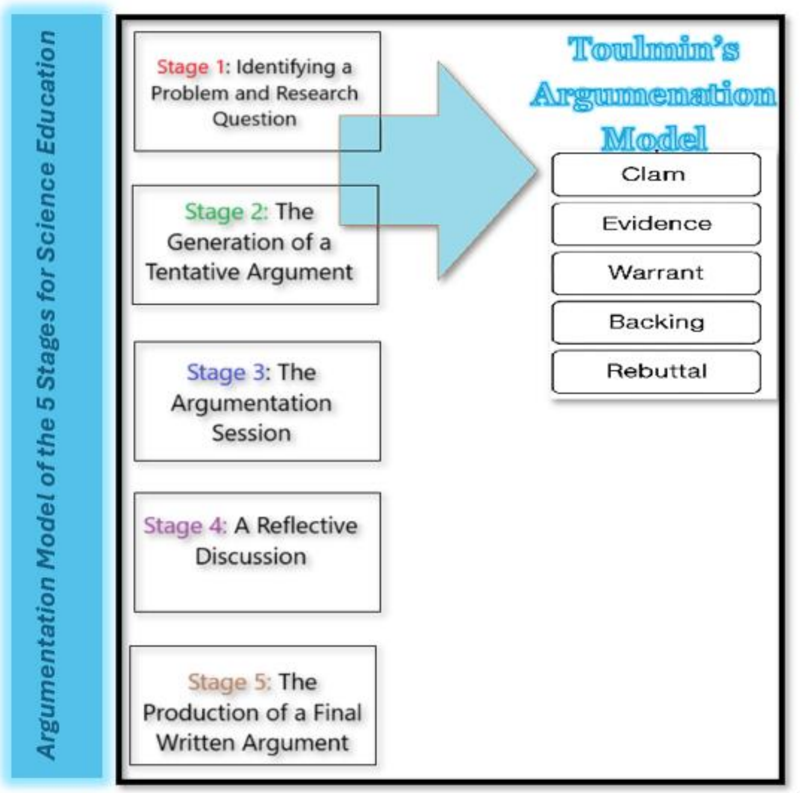


Table 1

The selected Biology Lessons from Grade 10 Biology subject

Activity (lesson)	*Title*	*Page*
Act. 3	The Use of the Synthesized Substances in Plants	52
Act. 6	The Coding and Treatment of The Nervous Information	74
Act. 3	Production of High-Quality Plants in a Large Number	106
Act. 4	Greenhouse Cultures	125
Act.6	Degradation and Protection of Soil	184

Grade 10 Biology Book is titled Secondary Education First Year for the Scientific Grade Level and published by the Center for Educational Research and Development. Many biology teachers and coordinators cooperated to establish this book initially in 1998 and have kept updating it until 2017.

This book is designed as a set of activities for students to explore the content and explain it through research and inquiry-based learning. Unlike previous books, where students were left with paragraphs per lesson to memorize, this book includes areas for students to use their scientific skills and manipulate their information to conclude the rationales of every lesson and apply them in daily life. Unfortunately, biology teachers didn’t achieve the vision of the authors and reverted to traditional teaching methods that rely completely on the teacher and physical white or chalkboards. These teachers still follow lectures daily, with a few lab experiments, if available, to explain these lessons.

The purpose of selecting these Biology Lessons

Regarding the poor lecturing methods in teaching these lessons and the absence of student participation and engagement in the explanations, these are just two reasons out of many that inspired me to search for models and styles in teaching biology based on student-centered styles and techniques.

The areas of discussion and debate are not utilized effectively in the classes. The assessments rely on solid memorization of the information rather than research for case studies or certain investigations that guide students to solve a problem by using technology or the internet. All the selected lessons based on sociocultural content could be opened for large discussion sessions because they are sociocultural scientific subjects that enable every student to acquire certain scientific positions. Eventually, this sort of discussion is not only helpful for the students as the targets but for the teacher as well, as the teacher can dig into and explore the scientific misconceptions of these students.

Grade 10 students are stubborn teenagers who have accumulated a large variety of data throughout their years and may struggle to defend their ideas even though they have acquired faulty information.

It needs to be noted that there was no formal biology lesson plan that integrated many argumentative models and could be customized to serve the Lebanese educational system. This is why, after many readings and much research, Toulmin's Framework was shortlisted and attracted my attention—due to its logically sequential elements that can be applied to everyday issues and can build students' scientific personalities—to manipulate and customize it according to the grade level, lesson titles, and the objectives of every lesson. Then, when setting the physical lesson plan, another gap was easily discovered, which was managing the time effectively based on student engagements and tasks. The solution was to divide every lesson into stages or stations that have a sub-objective and a specific allotted time independently.

Designed Lesson Plan: Designed based on merging of Toulmin's Argumentation Framework and Argumentation Model.

Components of the Lesson Plan:

- Title of the Lesson: To introduce the students to the topic and to have a clear idea of what they will be learning.
- Objectives: Objectives outline what students should know or be able to do by the end of the lesson. In argumentative lessons, the objectives often involve critical thinking, analyzing evidence, and developing arguments based on scientific data.
- Introduction: The introduction grabs the students' attention and introduces the topic in a way that sparks curiosity. It may present a controversial issue or a real-world problem related to biology.

. Stages of Lesson Plan:

Stage 1: The identification of a problem and the research question

Introduction: (Introduce the research questions that the students will answer during the argumentation session.)

Context settings: (Explain that students will use the Toulmin argumentation framework to support their claims.)

Instructions: (Review the Toulmin model with the class:)

Claim: A statement or conclusion that answers the research question.

Evidence: Data or observations that support the claim.

Warrant: The reasoning that links the evidence to the claim.

Backing: Additional information that reinforces the warrant.

Rebuttal: Acknowledging and addressing conflicting evidence or alternative explanations.

Group work: (Divide the students into small groups (3-4 students per group) to begin the inquiry activity.)

Stage 2: The generation of a tentative argument

Group work

Each group examines the provided data set or observations.

Students use the Toulmin framework to develop a tentative argument:

Claim: Answer to the research question.

Evidence: Choose relevant data points to support the claim.

Warrant: Reasoning explaining how the evidence supports the claim.

Backing: Use additional knowledge or concepts to reinforce the warrant.

Rebuttal: Address any potential counterarguments.

Teacher Support: The teacher circulates around the room, asking probing questions to guide students through the argumentation process (e.g., "What data supports your claim?" or "How do you know your evidence is reliable?").

Stage 3: The argumentation session

Presentation Format:

In a round-robin format, one member of each group stays at their workstation to present their argument while other students rotate to different groups to critique the arguments.

Peer Evaluation:

As students present their arguments, others listen and provide constructive feedback based on the Toulmin model.

The teacher can ask critical questions to encourage evaluation of evidence and reasoning (e.g., "Does this evidence fully support the claim?" or "What alternative explanations can you consider?").

Revision of Arguments: After the argumentation session, students return to their original groups and modify their tentative arguments based on peer feedback.

Stage 4: A reflective discussion

Whole-Class Discussion:

The teacher leads a discussion about what students learned through the argumentation process.

Encourage students to share insights about the research question and how their thinking evolved during the activity.

Reflection:

Discuss common challenges students encounter when generating and refining their arguments.

Encourage students to reflect on the importance of using evidence to support claims and to evaluate the validity of other arguments.

Stage 5: The production of a final written argument

Final Argument Writing:

Each student writes an individual final argument, using the Toulmin framework to organize their thoughts.

Students should include:

A claim answering the research question.

Relevant evidence from the data: A supported warrant that explains why the evidence is relevant.

Backing from scientific principles or additional research.

A rebuttal to alternative explanations or conflicting evidence.

Writing Prompt:

Provide students with a prompt to guide their writing.

Example: “Write an argument answering the research question. Support your claim with evidence from the data and explain why the evidence supports your conclusion. Consider any counterarguments or conflicting evidence and address them in your argument.”

Submission: Students submit their written arguments for evaluation. The teacher uses the Toulmin model rubric to assess clarity, evidence, and reasoning.

Assessment: Assessing students’ arguments allows teachers to measure whether the lesson's objectives have been achieved and whether students can apply their learning to construct well-supported arguments.

Argument Rubric:

Evaluate students’ final written arguments based on the following criteria:

Claim: Clear and well-supported statement answering the research question.

Evidence: Relevant and sufficient data used to support the claim.

Warrant: Logical reasoning linking evidence to claim.

Backing: Additional supporting information that strengthens the warrant.

Rebuttal: Addressing conflicting evidence or alternative explanations.

Writing Quality: Organization, clarity, and adherence to scientific argument conventions.

Table 2

Rubrics of Evaluation of Toulmin's Framework

Criteria	5 – Exemplary	4 - Proficient	3 - Satisfactory	2 - Developing	1 - Beginning
Claim	The claim is clear, precise, and appropriately qualified (e.g., "typically," "likely"). It directly answers the research question and is strongly supported.	The claim is mostly clear and relevant, with some qualifying language.	The claim is somewhat clear but may lack qualification or full relevance to the question.	The claim is unclear or too broad/generalized, with weak connection to the research question.	The claim is missing or unrelated to the task.
Evidence	Uses multiple, relevant, and well-chosen data points or observations. Evidence is clearly explained and tied to the claim.	Jse relevant evidence and explain it clearly, though some connections may be implicit.	Evidence is present, but explanation or connection to the claim is basic or vague.	Evidence is limited, unclear, or only somewhat related to the claim.	Evidence is missing, unrelated, or incorrect.
Warrant	It shows strong reasoning, linking evidence to claim, with logical flow and scientific accuracy. Reasoning is explicit and well-developed.	Reasoning is mostly clear and logical, showing understanding of how evidence supports the claim.	Reasoning is basic, or connections between claim and evidence are not fully explained.	Reasoning is weak or partially incorrect; it shows confusion or gaps in logic.	No warrant is provided or contains flawed logic.
Backing	Provides scientifically accurate, additional support (e.g., principles, diagrams, prior knowledge) to reinforce the warrant.	Provides relevant additional information to support reasoning, though it may lack full detail.	Provides some backing, but it may be general, incomplete, or only somewhat relevant.	Minimal or weak backing that adds little value.	No additional support is provided.
Rebuttal	Thoughtfully addresses alternative views, counterarguments, or limitations using scientific reasoning.	Addresses an alternative explanation or exception with reasonable response.	Mentions a counterargument but response is brief or underdeveloped.	Mentions counterpoint but lacks explanation or clarity.	No rebuttal or ignores possible alternative views.
Use of Qualifying Language	Consistently uses qualifiers (e.g., "often," "may," "typically") to reflect scientific uncertainty and avoid overgeneralization.	Usually, qualifying language appropriately.	Occasionally qualifiers are used; some generalizations present.	Rarely uses qualifiers; arguments are overly certain or generalized.	Does not use qualifying language; frequent overgeneralizations.
Writing Quality	Writing is well-organized, coherent, and scientifically appropriate. No grammar issues.	Writing is mostly clear and structured, with few errors.	Writing is adequate but may lack clarity or organization.	Writing is somewhat confusing, with several language or structure issues.	Writing is unclear, disorganized, or inappropriate in style/tone.

CHAPTER 4

RESULTS

This chapter presents the results of a study aimed at designing and developing six lesson plans based on Toulmin's model of argumentation. Its purpose is to provide a detailed account of the instructional materials produced and to demonstrate how Toulmin's argument structure was operationalized within each lesson. Although the lesson plans were not implemented in an authentic classroom context, their systematic construction offers valuable insights into translating argumentation theory into practical teaching resources.

The results are presented concerning the extent to which the essential components of Toulmin's framework—claim, evidence, warrant, backing, rebuttal, and qualifier—were explicitly integrated into the lesson objectives, activities, and assessment opportunities. The analysis highlights not only the presence of these elements but also their pedagogical coherence, clarity, and potential to foster students' higher-order thinking and reasoning skills.

Additionally, the chapter examines the alignment between the designed lesson plans and broader educational goals, such as promoting critical thinking, encouraging collaborative learning, and supporting evidence-based reasoning in science education. By analyzing the outcomes of the design process, this chapter reflects on the strengths, limitations, and areas for improvement in the lesson plans, particularly regarding their adaptability to diverse classroom contexts and learner needs.

Ultimately, the results presented here provide a foundation for understanding the instructional value of applying Toulmin's model in lesson planning. They also offer preliminary insights that could inform future implementation, classroom application, and empirical validation of the proposed materials in real educational settings.

In addition to creating six Toulmin-based lesson plans, this study emphasizes the importance of designing a digital teacher portal dedicated to the Biology subject. Such a portal would serve as a centralized platform to collect, organize, and store all teaching materials, including lesson plans, quizzes, classroom activities, printables, and supplementary resources. By housing these instructional materials in a single, well-structured digital space, teachers can ensure that valuable resources are preserved from one academic year to the next. This approach prevents duplication of effort and creates a growing repository of content that can be continuously enriched and refined over time. The presence of a teacher portal transforms instructional planning from an isolated practice into a sustainable and collaborative process that supports long-term curriculum development.

Moreover, a teacher portal enhances both accessibility and communication. Resources stored within the portal can be easily shared with students to facilitate independent learning and revision, while administrators can access these materials to monitor instructional alignment with school standards and curriculum objectives. The digital platform acts as a bridge between teachers, students, and school leadership, ensuring transparency and consistency in instructional delivery. In the case of the Toulmin-based Biology lesson plans, the portal would provide an efficient means of implementation, enabling teachers to adapt and reuse structured argumentation resources while supplementing them with new quizzes and activities. Over time, this system would not only strengthen resource management but also foster a culture of collaboration and innovation in Biology education.

Table 3

Lesson plan topics with the objectives

Lesson Plan	Title/ Topic	Objectives	Duration
1	The Use of the Synthesized Substances	Students should be able to indicate the presence of the stored substances in the green plant.	8 sessions
2	The Coding and The Treatment of Nervous System	Students should be able to differentiate between the decentral and the central nervous system by using the oscilloscope and graphing analysis.	8 sessions
3	Production of High-Quality Plants in Large Amounts	Students should be able to differentiate between Traditional and the Modern Methods of Cultivation	8 sessions
4	Greenhouse Cultures	Students must indicate the importance of the limiting factors that involve in the green house plant culturing through argumentation and class activities.	8 sessions
5	Intensive Exploitation of Water	Students should identify that water is limited and not easy to renew its sources as many people think. Students must indicate the consequences of the intensive exploitation regarding the collecting of water in the underground wells.	8 sessions
6	Degradation and Protection of Soil	Students will be able to evaluate the impact of unsustainable agricultural practices—such as monoculture, excessive irrigation, overgrazing, and intensive farming—on soil degradation. Students will be able to analyze the biological and environmental consequences of human activity and overpopulation on soil degradation.	8 sessions

Table 4

Different Classwork and Homework activities during Toulmin Argumentation Lesson Plans

Classroom/ Homework Activities Type	Lesson Plan					
	1	2	3	4	5	6
Lab investigation (students only)	✓	✓	✓	✓	✓	✓
Experiment (with the teachers' help)	✓	✓	✓	✓	✓	✓
Graded homework	✓	✓	✓	✓	✓	✓
Presentation	✓	✓	✓	✓	✓	✓
Reflective discussion	✓	✓	✓	✓	✓	✓
Collaborative learning KAGAN	✓	✓	✓	✓	✓	✓
Think -pair-share	✓	✓	✓	✓	✓	✓
Writing skills	✓	✓	✓	✓	✓	✓
Icebreakers	✓	✓	✓	✓	✓	✓
Demonstration	✓	✓	✓	✓	✓	✓

Table 5

The distribution of Toulmin Elements across all the lesson plans

Toulmin Element	Lesson plan 1	Lesson plan 2	Lesson plan 3	Lesson plan 4	Lesson plan 5	Lesson plan 6
Claim	✓	✓	✓	✓	✓	✓
Evidence	✓	✓	✓	✓	✓	✓
Warrant	✓	✓	✓	✓	✓	✓
Qualifier	✓	✓	✓	✓	✓	✓
Backing	✓	✓	✓	✓	✓	✓
Rebuttal	✓	✓	✓	✓	✓	✓

The Toulmin-based argumentative lesson plan begins with three essential components that set the foundation for meaningful and engaging instruction: the title, learning objectives, and the introduction. The lesson title provides immediate context and signals to students the central topic or theme they will explore. It plays a subtle but powerful role in activating prior knowledge and shaping students' expectations. The objectives, however, are where the true instructional focus is defined. In the Toulmin template, objectives are not limited to content recall; they include goals related to scientific reasoning, argument construction, and evaluating evidence. Clear objectives have been shown to significantly enhance student focus and achievement by giving learners direction and a sense of purpose (Anderson & Krathwohl, 2001). The introduction section builds on this by capturing students' attention through real-world issues, controversial biological topics, or sociocultural dilemmas. Presenting an issue that sparks curiosity, and emotion helps frame the lesson within a personally relevant context (Marzano et al., 2007). This is particularly effective in Lebanon, where biology curricula often lack structured opportunities for inquiry-based engagement, and where argumentative teaching can fill the gap by motivating students to explore complex biological and ethical issues critically.

The next major phase of the Toulmin template is content presentation, where foundational scientific knowledge is delivered in a way that supports argumentation. In this step, the teacher introduces the key biological facts, data sets, or conceptual frameworks that students will need to construct their arguments. The emphasis here is not simply on knowledge transmission but on providing learners with the tools to reason and question. Research confirms that students retain and understand scientific content more effectively when it is linked to problem-solving or argumentative tasks (Freeman et al., 2014). For instance, if the lesson topic is about the ethics of genetic modification, students might be presented with data on genetic engineering practices, success rates, and ethical debates from the scientific community. This equips them with the raw material they will later analyze during argumentation. Teachers play a critical role here in selecting content that is accessible, evidence-rich, and framed around questions that support multiple viewpoints. This ensures that students are not merely passive recipients of information but active participants in constructing meaning from the scientific content they are exploring.

The third component—guided practice—is a collaborative stage where students begin formulating their arguments with structured teacher support. This is the bridge between content acquisition and independent argumentation. During guided practice, students might work in pairs or small groups to interpret a graph, evaluate claims, or brainstorm potential warrants and rebuttals based on the Toulmin model. This aligns with the scaffolding theory proposed by Wood, Bruner, and Ross (1976), which emphasizes the importance of social interaction and teacher guidance in developing higher-order thinking. In the context of Lebanese classrooms, where curriculum materials often omit opportunities for guided scientific discourse, this stage is crucial in modeling the thought processes behind scientific reasoning. By interacting with peers and receiving feedback from the teacher, students begin to internalize argumentative structures and develop confidence in their reasoning abilities. Moreover, this phase supports collaborative learning, enabling students to refine their perspectives, clarify misunderstandings, and practice articulating claims and counterclaims in a respectful, evidence-based manner.

following guided instruction is independent practice, where students are expected to apply what they have learned on their own. this stage requires students to independently formulate a claim, support it with evidence, explain their reasoning (warrant), and, when applicable, address possible counterarguments.

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Educational Use of Toulmin's Model

The development of six lesson plans based on Toulmin's model of argumentation provides several important theoretical insights. Although the lessons were not implemented in real classroom contexts, the design process illustrates the adaptability of Toulmin's framework for educational use. By transforming the abstract elements of claim, evidence, warrant, backing, rebuttal, and qualifier into structured teaching resources, this study highlights the potential of argumentation theory to transcend its philosophical roots and become a practical pedagogical tool. In this way, the research contributes to validating the applicability of Toulmin's model in supporting the teaching of reasoning, critical thinking, and structured dialogue within formal educational settings. The lesson plans serve as evidence that argumentation models can be concretized into accessible resources, bridging the long-standing gap between theory and classroom practice.

Supporting Structured Argumentation in Classroom

From a pedagogical perspective, the lesson plans offer clear guidance to teachers in structuring argumentation activities. They provide step-by-step scaffolds that enable educators to help students distinguish between claims and evidence, articulate logical connections through warrants, and reinforce reasoning with rebuttals and qualifiers. Such structured guidance has the potential to support learners in gradually developing sophisticated reasoning skills. Moreover, the plans can be adapted to diverse subject areas, including science, social studies, and language arts, enhancing their relevance across curricula. Importantly, the design also implies a shift in assessment practices.

Rather than focusing solely on content recall, teachers could use these lessons to evaluate the quality of students' reasoning, their ability to justify claims, and their capacity to engage with counterarguments.

Integrating Argumentation in Curriculum design

The creation of these lessons also carries practical implications for curriculum design and professional development. By embedding argumentation into the fabric of daily teaching, schools could foster a culture of inquiry-based and student-centered learning. The structured progression of Toulmin's elements across the six lessons demonstrates how critical thinking skills can be scaffolded, beginning with simple claims and evidence and advancing toward more complex arguments involving qualifiers and rebuttals. Furthermore, teacher preparation programs may use these lesson plans as exemplars to demonstrate how abstract argumentation frameworks can be applied in classroom instruction. In this sense, the study not only offers resources for immediate classroom use but also contributes to teacher education and curriculum innovation.

Challenges in Implications

Despite these contributions, the study also faces several limitations. Most notably, the lesson plans were not piloted or tested with actual student groups, meaning their effectiveness remains theoretical and unverified in real classroom environments. Furthermore, the impact of such lessons may vary considerably depending on the subject matter, the age and prior knowledge of learners, and the pedagogical skills of teachers. The success of Toulmin-based instruction is heavily dependent on the teacher's ability to facilitate discussions, encourage critical dialogue, and manage diverse perspectives. Without classroom application, it is challenging to determine how students will respond to these lessons in practice or what challenges teachers may encounter during implementation.

Future Research and Practices

Finally, the study points toward several promising directions for future research and practice. A logical next step would be to pilot test these lesson plans in actual classrooms to examine how effectively they enhance student reasoning and critical thinking. Comparative studies could also be conducted to explore differences between Toulmin-based instruction and more traditional teaching methods, providing empirical evidence of their impact. Additionally, integrating these plans into digital platforms or argument-mapping tools may extend their accessibility and foster more interactive learning. The adaptability of Toulmin's framework across multiple disciplines suggests that cross-curricular applications could be explored in future studies. By doing so, the impact of Toulmin's model on students' reasoning and argumentation skills can be more fully realized and documented.

CHAPTER 6

CONCLUSION, RECOMMENDATIONS AND FUTURE DIRECTIONS

Biology education in today's rapidly evolving world is no longer merely about memorizing facts and diagrams; it focuses on cultivating thinkers, problem-solvers, and socially aware individuals. However, the current Lebanese curriculum falls short of this vision. It lacks modern pedagogical methodologies that guide teachers in promoting critical thinking and inquiry-based learning. Key components, such as guided questions, opportunities for student responses, and the development of practical and argumentative skills, are largely absent. Consequently, students often perceive biology as a rigid, content-heavy subject rather than a dynamic exploration of life and society.

To bridge this gap, there is a pressing need to incorporate argumentative teaching methods, particularly when addressing sociocultural topics within biology. Argumentation fosters deeper understanding, enhances long-term memory, and encourages meaningful student engagement. It empowers learners to question, reason, and communicate effectively—skills that are essential in the 21st century. By embedding structured debate and discussion into biology lessons, we not only enrich scientific understanding but also develop students' social, communication, and collaborative abilities. This shift is crucial for preparing students for a future that demands both scientific literacy and civic engagement.

Biology education in Lebanon suffers from more than outdated content—it suffers from outdated methods. Teachers are expected to foster inquiry and engagement, yet they are provided with a rigid curriculum that offers no space for student responses, no room for opinion-based learning, and no clear guidelines for developing critical thinking skills (El-Hage et al., 2019). In this environment, argumentation, especially using structured frameworks like Toulmin's model—is almost entirely absent.

The Toulmin model, which breaks arguments down into claims, evidence, warrants, backings, rebuttals, and qualifiers, is a powerful tool for structuring reasoning (Toulmin, 2003). It transforms classroom debates from simple opinion-sharing to disciplined thinking. However, most biology teachers have never been introduced to this model, let alone trained to implement it in lessons (Erduran & Jiménez-Aleixandre, 2007). This lack of exposure is not the fault of the teachers themselves, but of a system that has not prioritized argumentative pedagogy as a core teaching skill.

Without Toulmin's structure, biology discussions—particularly those involving sociocultural or ethical topics like genetics, cloning, or environmental responsibility—remain shallow. Students are not guided to question evidence, to back their claims, or to consider counterarguments. As a result, they miss the chance to build long-term understanding, refine their communication skills, and develop 21st-century competencies such as critical thinking and collaborative dialogue (Osborne, 2010).

To move forward, teacher training programs must integrate Toulmin's model as a fundamental component of pedagogy, especially in subjects like biology where scientific reasoning and social awareness often intersect. Empowering teachers with this tool will allow them to foster more dynamic, discussion-rich classrooms where learning is driven by exploration, not just explanation.

In a world where science and society are increasingly interconnected, our students deserve more than facts, they deserve the skills to think, question, and argue effectively. And our teachers deserve the methodologies to guide them there.

In conclusion, future research should explore how to effectively redesign Lebanese biology lesson plans by integrating structured argumentation models, such as Toulmin's, to overcome current pedagogical limitations. Empirical studies comparing traditional, content-heavy approaches with argumentative lesson structures, particularly in sociocultural and ethical science contexts—can provide valuable insights into which methods best foster critical thinking, communication, and student engagement (Osborne, 2010). Additionally, exploratory research is needed to identify effective sequences for embedding argumentation into science lessons in a way that supports students' cognitive development and inquiry skills (Erduran & Jiménez-Aleixandre, 2007). The findings of such research could guide the development of instructional models that move away from rigid, lecture-based formats toward dynamic, student-centered learning experiences (Sadik & Al-Husseini, 2020).

Integrating argumentation into lesson planning is not only essential for enhancing student outcomes but also for redefining the teacher's role as a facilitator of reasoning and dialogue. Designing such lessons requires more than curriculum revision—it demands strong teacher preparation. In Lebanon, where many educators are not trained in modern pedagogical frameworks, there is an urgent need for professional development focused on argumentative teaching (Sadik & Al-Husseini, 2020). Training programs should equip teachers with tools like Toulmin's model (Toulmin, 2003), model lesson plans, and practical strategies to scaffold argumentation in classrooms. Supporting teachers through ongoing training and collaborative planning can empower them to create inclusive, discussion-rich science lessons that promote 21st-century skills such as critical thinking, communication, and civic engagement (Osborne, 2010).

This transition from guided to independent work is essential for mastery and is closely linked to academic achievement (Hattie, 2009). In argumentative biology lessons, independent practice can take the form of writing a scientific essay, preparing for a structured debate, or responding to a scenario-based prompt. Through this process, students are not only demonstrating their understanding of the biological content but also practicing scientific inquiry skills such as evidence evaluation and logical reasoning. As Zohar and Nemet (2002) argue, argumentation supports the development of higher-order thinking, such as analysis, synthesis, and evaluation—key components of scientific literacy. In regions like Lebanon, where independent thinking is not strongly emphasized in the curriculum, incorporating independent argumentative tasks encourages autonomy, deepens content understanding, and empowers students to engage more confidently with scientific and societal issues.

Facilitated by the teacher, this discussion can take the form of classroom debates, Socratic seminars, or panel presentations. This structure builds critical communication skills, such as listening, negotiating meaning, and respectfully challenging others' viewpoints. It also promotes civic and ethical reasoning, as students must consider the societal impact of biological issues like vaccination policies or environmental conservation. Such discussions are transformative because they shift the role of the student from a passive learner to an active knowledge producer. In Lebanese classrooms, which often emphasize rote learning and one-directional instruction, embedding structured argumentation is a powerful strategy for promoting student voice, encouraging inquiry, and building collaborative scientific dialogue.

Finally, the Toulmin lesson plan template concludes with assessment, summary, and reflection, which are essential for reinforcing learning and promoting metacognition. Assessments in this model are designed not only to evaluate factual understanding but also to measure students' ability to build and support coherent arguments. This aligns with the formative assessment principles outlined by Black and Wiliam (1998), who argue that assessment should inform teaching and support learning, not just grade performance. Teachers may assess students through written arguments, oral presentations, or interactive rubrics that evaluate argument structure, use of evidence, and clarity of reasoning. The summary phase helps reinforce key concepts and ties the argumentation process back to the biological content. Reflection activities—such as journals, peer evaluations, or exit slips—invite students to consider how their thinking evolved and how their argumentation skills might apply to other topics. This reflective component encourages metacognitive awareness and fosters a lifelong learning mindset (Schraw, 1998). To successfully implement all these stages, it is crucial that teachers receive pedagogical training in argumentation, especially in contexts like Lebanon where traditional instructional models dominate. Providing educators with the tools, time, and support to shift toward this model is key to creating inquiry-driven, student-centered biology classrooms.

A comprehensive joint booklet was prepared, containing six fully designed Toulmin-based argumentative lesson plans aligned with the official Grade 10 Biology textbook used in the Lebanese national curriculum. Each lesson plan was adapted to integrate inquiry-based learning and structured argumentation strategies aimed at enhancing student engagement, critical thinking, and scientific reasoning. In addition, a dedicated digital portal was developed to serve as an interactive platform through which teachers can display, access, and archive the lesson plans alongside related teaching tools, including worksheets, assessment rubrics, and multimedia resources. This platform was designed to ensure long-term accessibility, flexible instructional use, and foster collaboration among educators by providing a centralized repository of pedagogical materials.

APPENDIX 1

LESSON PLAN TEMPLATE

Argumentative Biology Detailed Lesson Plan Template

1. Title of the Lesson:	
Reason:	The title sets the context for the lesson and gives students a clear idea of what they will be learning.

Citation: Research on instructional design emphasizes the importance of clear objectives and context to engage learners (Mayer, 2011).

2. Objective(s)	
Reason:	Objectives outline what students should know or be able to do by the end of the lesson. In argumentative lessons, the objectives often involve critical thinking, analyzing evidence, and developing arguments based on scientific data.

Citation: Clear learning objectives help students focus on key goals, which improves achievement (Anderson & Krathwohl, 2001).

3. Introduction:	
Reason:	The introduction grabs the students' attention and introduces the topic in a way that sparks curiosity. It may present a controversial issue or a real-world problem related to biology.

Citation: According to Marzano et al. (2007), a strong introduction is crucial for framing the lesson and creating a purpose for learning.

4. Content Presentation	
Reason:	This part involves the direct teaching of the content. In an argumentative biology lesson, it typically involves the presentation of scientific facts, data, or concepts necessary to support the argument.

Citation: Active learning, including presenting content that students can later argue about, improves retention and understanding (Freeman et al., 2014).

5. Guided Practice	
Reason:	This is a collaborative phase where students start to form their arguments with teacher guidance. It may involve analyzing a case study, interpreting data, or discussing an issue.

citation: Providing opportunities for guided practice helps reinforce concepts and provides scaffolding for deeper learning (Wood, Bruner, & Ross, 1976).

6. Independent Practice	
Reason:	Independent practice gives students the opportunity to independently form and express their arguments, demonstrating their understanding of the content and the ability to defend their position.

Citation: Independent practice encourages mastery of the material by providing students with the space to apply what they have learned on their own (Hattie, 2009).

7. Discussion and Argumentation	
Reason:	This part involves a structured debate or discussion where students present and defend their arguments, using evidence from the lesson. It allows students to critically engage with the material and think about alternative viewpoints.

Citation: Argumentation promotes higher-order thinking skills, such as analysis and synthesis, which are essential for developing scientific literacy (Zohar & Nemet, 2002).

8. Assessment	
Reason:	Assessing students' arguments allows teachers to measure whether the lesson's objectives have been achieved and whether students can apply their learning to construct well-supported arguments.

Citation: Formative assessments, such as arguments, can provide valuable feedback on students' thinking and comprehension (Black & Wiliam, 1998).

9. Conclusion	
Reason:	The conclusion summarizes key points from the lesson and reinforces the importance of the argument. It also connects the lesson to future learning or real-world applications.

Citation: Summarization is an effective strategy for reinforcing learned content (Roediger & Butler, 2011).

10. Extension/Reflection	
Reason:	This part encourages students to reflect on the lesson and extend their learning. It might include homework, further reading, or a reflection on how the argumentative skills learned can apply to other areas of science or life.

Citation: Reflection promotes metacognition, helping students become more aware of their learning process (Schraw, 1998).

APPENDIX 1
LESSON PLAN 1: THE USE OF SYNTHESISED SUBSTANCES

Argumentative Biology Detailed Lesson Plan Template

1. **Title of the Lesson: The Use of the Synthesized Substances** 2. **Grade Level: 10** 3. **Subject: Biology**	4. **Duration: 8 hrs. (2 wks.)** 5. **Topic: 3**

2. Objective(s): Students should be able to indicate the presence of the stored substances in the green plant.

Stage 1: The Identification of a Problem and the Research Question	
1.Introduction:	1. The lesson relates the nutrition process of the plants as photosynthesis to the source of the stored materials in the plants 2. The research questions: a) What is the relationship between the used organic materials and the materials that are produced or/and by plants?
2. Context Setting:	1- Provide students with the data set or observations that they will use to address the research question such as mounted slides of the phloem and the vacuoles in the green plants. 2- Explain that students will use the Toulmin argumentation framework to support their claims.
3. Instructions:	Review the Toulmin model with the class: ▪ **Claim**: Green plants produce glucose as a product of photosynthesis, this organic matter will be used later after storage into starch during respiration. ▪ **Evidence**: After the application and experimentation, testing two plants by allowing: **Experiment:** **a-** A control apparatus (App A) that has a green plant doesn't undergo photosynthesis due to lack of a limiting factor (such as avoiding sunlight or having limewater to absorb carbon dioxide). App A was exposed to the limiting factors for 72 hours. **b-** Another apparatus (App B) that has a green plant with all the available factors for photosynthesis, will have photosynthesis properly. **Observation:** **a-** Pick out two leaves from App A and App B respectively. **b-** Treat these two leaves with hot water, cold water and then hot alcohol for decolorizing them by removing the green chlorophyll. **c-** Add iodine on these two leaves and investigate the results. **d-** The appearance of blue color on the leaves means that starch exists that will indicate the existence of glucose as photosynthesis product. **e-** The brownish color of the leaf means that the plant couldn't make glucose due to the absence of photosynthesis such as App A.

	▪ **Warrant**: During photosynthesis, the green plan will synthesis glucose molecules that will be stored as starch. Plants need a way to store glucose for times when the plant strive without any of the limiting factors such as during night time or when the environmental factors are not available. Starch is considered as a long-term storage form because it is insoluble in water and inert that doesn't interfere in cellular processes. ▪ **Backing**: **As a scientific background**: **a-** Review the steps of photosynthesis process with the diagrams from grade 9. **b-** Photosynthesis is a chemical reaction that converts carbon dioxide gas and water liquids to carbohydrates such as reducing sugar (glucose) and oxygen gas in the presence of sunlight and chlorophyll. **c-** The hydrolysis of Starch will require the existence of enzymatic reactions. ▪ **Rebuttal**: While it is true that glucose is stored as starch, some might argue that glucose can be stored as sucrose (non-reducing sugar) and transported in the vacuoles of the green plants to be transported to phloem later. However, starch is the primary storage form because it is more stable and is stored in specialized organelles (plasmids such amyloplast), which don't interfere with the plant's regular metabolic reactions (anabolic).
4. Group Activity:	Divide the students into small groups (3-4 students per group) to begin the inquiry activity. The activity is in the form of printable paper have a question to answer: ***"You are given two apparatus A and B (as in the explanation), how do you think the presence of light and carbon dioxide affect the photosynthesis process and allows the glucose storage?*** **In pairs, discuss by using your prior knowledge to what you may observe in this experiment after treating with iodine test."**
5. Allocated time 50-60 minutes (explanation) , 20 minutes for group work and discussion.	

Stage 3: The Argumentation Session (60 minutes)

1.Presentation Format:

- In a round-robin format, one member of each group stays at their workstation to present their argument while other students rotate to different groups to critique the arguments.

2.Peer Evaluation:

- As students present their arguments, others listen and provide constructive feedback based on the Toulmin model.
- The teacher can ask critical questions to encourage evaluation of evidence and reasoning (e.g., "Does this evidence fully support the claim?" or "What alternative explanations can you consider?").

3.Revision of Arguments:

After the argumentation session, students return to their original groups and modify their tentative arguments based on peer feedback.

Stage 4: A Reflective Discussion

Time: 50-60 minutes

1. **Whole-Class Discussion:**
   - The teacher will use the white board to stick the diagrams of the photosynthesis equation and the green photosynthetic leaf that has many in and out arrows for the reactants and products.
   - The teacher also will start the discussion by writing the question on the board:

     How the light and carbon dioxide affect the rate of photosynthesis?

2. **Reflection:**
   - Ask the students in groups to answer these questions as separate ideas.
   - Allow the students to discuss ideas with each other.

Stage 5: The Production of a Final Written Argument

Time: 50-60 minutes

1. **Final Argument Writing:**
   - Each student writes an individual final argument, using the Toulmin framework to organize their thoughts.
   - Students should answer the following questions:
     - **Claim**: based on the experiment that you did with your friends, what can you conclude about the relationship of light and the concentration of carbon dioxide with respect to photosynthesis?
     - **Relevant evidence:** what is the available evident data that supports your conclusion of the relationship of light to photosynthesis?

Stage 2: The Generation of a Tentative Argument (3 hours- 180 minutes)

Group Work:

Every group will investigate botanical experiment "Study Photosynthesis with the Floating Leaf Disk Assay"

1. Each group is provided with a printed document
2. Students use the Toulmin framework to develop a tentative argument:

- **Claim:** the floating Leaf Disk Assay is an affective method for investigating photosynthesis by measuring the rate of oxygen production in green plants.
- **Evidence:** The floating leaf disk phenomenon is based on the floating of the cut circular pieces in a solution when exposed to light and carbon dioxide (when all the factors are available). The first evidence is that the oxygen gas that is produced is the leading factor of raising these disks to the surface of the solution, thus the rate of oxygen production is the same as the rate of photosynthesis, thus if more oxygen is produced the more photosynthesis and glucose production occurs).
    i. Thus, the students should notice the importance of this experiment as a quantitative method that ends up by graphical presentation of the results and allow analysis and conclusion based on this evidence.
    ii. **Experimental Observation**: what is significant is the solution that the discs are emerged in it, this is a bicarbonate solution and exposed to light. The discs sink as photosynthesis occurs, the driving force is the production of oxygen.
    iii. Control apparatus: this apparatus will have one limiting factor that avoids photosynthesis and thus the discs will sink rather than floating due to the absence of the driving force.
- **Warrant:** The mentioned evidence of the occurrence of photosynthesis will indicate the importance of light and carbon dioxide as important factors for this process. Since we can't directly evident and prove the existence of photosynthesis, the easiest way is to wait for the oxygen collection and since it is collected in the air spaces, this will enable the discs to float.
- **Backing: Scientific principle:** photosynthesis is a chemical process that is driven by the action of light solar energy. Oxygen is a by-product, and its release can be measuring also by the use of an indicator for photosynthetic activity. The floating leaf experiment can be a measurable vital way to track this oxygen production.
- **Rebuttal**: Some people argue that this experiment is not a precise quantitative method for measuring photosynthesis because only oxygen is measured which is only one aspect rather than other products. Besides the surface area is ignored or the concentration of the bicarbonate concentration that will also are factors of the movement of discs.

Teacher Support:

1. The teacher circulates around the lab, asking probing questions to guide students through the argumentation process (e.g., "What data supports your claim?" or "How do you know your evidence is reliable?").
2. Every group of students who are given the printables will be provided with rubric as well and time- table that will help them to work accordingly and to achieve the task on time.
3. The task accomplishment is fulfilled after the submission of the graphic paper that studies the rate of oxygen with passing time.

- **A supported warrant:** Why does the collected data about oxygen concentration that is represented as the rate, support the conclusion of the effect of light factor on photosynthesis?
- **Backing from scientific principles:** What is your background information about other factors for photosynthesis that will also control the occurrence of photosynthesis?
- **Rebuttal:** How can we alter this process by changing other factors not only light?

2. **Writing Prompt:**
   - Provide students with a prompt to guide their writing.

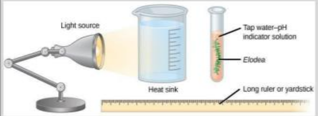
     1. *The teacher will motivate her students to write a scientific argumentative paper that starts with the research question.*
     2. *The teacher also will ask the students to support their claim with evidence from the data and explain why the evidence supports their conclusion.*
     3. *The teacher will allow the students also to consider any counterarguments or conflicting evidence and address them in their argument.*
     4. *The students are provided with rubrics and due dated of submission via email on the school platform.*

3. **Submission:** Grading will be based on the rubrics and on the sharp submission date.

8. Assessment- Graded Homework

Reason: Assessing students' arguments allows teachers to measure whether the lesson's objectives have been achieved and whether students can apply their learning to construct well-supported arguments.

Assessment: the students are given a similar experiment or investigation to solve:



Title: Influence of Light Reaction on The Concentration of CO2

1. **The details of this experiment in the attached link:** https://louis.pressbooks.pub/generalbiology1lab/chapter/influence-of-the-light-reaction-on-the-concentration-of-co2/
2. **After completing the lab, the student will be able to:**

A. Measure the dependence of CO_2 fixation on the light-dependent reaction.
B. Explain the chemical principles of pH indicators and the bicarbonate-CO_2 equilibrium.

3. **The students will be graded after answering one of the case scenario and NOT the three and submitting the answers of these three questions:**

A- In an experiment, the water was first boiled, which drove out all of the existing gases. The water was then added to the test tube containing *Elodea*, which was then exposed immediately to light. The photosynthetic activity of the *Elodea* was then monitored but no photosynthetic activity was detected. How can you correct the situation by modifying the composition of the *Elodea* environment?

B- Scientists report that the levels of carbon dioxide are rising in the atmosphere and driving climate change. Another observation is that the acidification of oceans is also a consequence of climate change. Can you explain what link may exist between the two phenomena and how it affects the marine ecosystem?

C- Farmers report that planting corn plants too closely can stunt growth even when the plants are heavily fertilized and receive plenty of light. Furthermore, the effect seems to be reduced in recent years. What is the growth limiting factor under these conditions? What may be an explanation? How do plants respond to decreased availability of the limiting factor?

Writing Quality: Organization, clarity, and adherence to scientific argument conventions.

9. Extension/Reflection (60 minutes)

Reason: *This part encourages students to reflect on the lesson and extend their learning. It might include homework, further reading, or a reflection on how the argumentative skills learned can apply to other areas of science or life.*

After the lesson, the teacher reflects on how effectively students engaged in the inquiry and argumentation process. Were students able to use evidence effectively to support their claims? Did they engage in meaningful critique of their peers' arguments? What improvements can be made for future lessons?

Procedure:

A- The teacher designed a questionnaire that the student will receive and answer it individually.

B- The teacher may have an online virtual game that will help the students to challenge as two groups to test the student knowledge.

C- The teacher may ask the students to write suggestions to write their feedback and reviews about their new experience in explain based on argumentation.

APPENDIX 2

LESSON PLAN 2: THE CODING AND THE TREATMENT OF NERVOUS SYSTEM

Argumentative Biology Detailed Lesson Plan Template

1. Title of the Lesson: The Coding and The Treatment of Nervous System 2. Grade Level: 10 3. Subject: Biology	4. Duration: 8 hrs. (2 wks.) 5. Topic: 3

2. Objective(s): Students should be able to differentiate between the decentral and the central nervous system by using the oscilloscope and graphing analysis.

Stage 1: The Identification of a Problem and the Research Question	
1.Introduction:	1. The lesson explores the comparison between the sensory and the motor neurons through experimentation. 2. The research questions: How do sensory neurons and motor neurons differ in their structure and function, as demonstrated through experimentation by referring to the action potential graphs?
2. Context Setting:	1- The lesson is based on experimentation to investigate how Pacinian Corpuscles detect pressure using an oscilloscope. 2- Explain that students will use the Toulmin argumentation framework to support their claims.
3. Instructions:	Review the Toulmin model with the class: Title: Investigating How Pacinian Corpuscles Detect Pressure Using an Oscilloscope. ▪ **Claim**: Pacinian Corpuscles generate action Potential in response to mechanical pressure, and these signals can be detected and measured using oscilloscope when the corpuscle is placed in a saline solution. ▪ **Evidence**: Previous corpuscles generate action potentials in response to mechanical pressure by converting them into electrical nerve impulse (action potentials). These impulses follow a "all-or-none" response pattern and increase in frequency with stronger stimuli. **Experiment:** **a-** To observe the electrical activity (action potentials) of Pacinian Corpuscle when subjected to mechanical pressure. **b-** Used Materials: isolated Pacinian Corpuscles, saline solution, microelectrodes, probe to apply mechanical pressure (glass rod or fine brush), microscope. **Procedure:** **a-** Place the Pacinian corpuscle in a Petri dish filled with warm saline to keep it viable. **b-** Insert microelectrodes, one connected to the nerve fiber and the other grounded in the solution. **c-** Connect electrodes to the oscilloscope. **d-** Gently press the corpuscle using the probe. **e-** Observe and record the oscilloscope readings. **f-** Apply pressures of different strengths and durations and compare the graph. **Observation:** 1- When pressure is applied the oscilloscope shows spikes (action potentials) 2- A light touch may produce few or no spikes. 3- Stronger pressure results are more frequent or higher spikes. 4- Once the pressure is removed the spike stops. These results demonstrate that the Pacinian Corpuscle is sensitive to mechanical changes. ▪ **Warrant**: If a structure produces electrical signals in response to physical stimuli, it is acting as a mechanoreceptor, since the corpuscle generates measurable action potential when touched. This supports the claim that it detects and responds to mechanical pressure. ▪ **Qualifiers:** 2. This experiment best works with fresh biological samples. 3. Results may vary based on the temperature, electrical placement on pressure technique. 4. Only certain types of stimuli (vibration, pressure) activate the Pacinian Corpuscle. ▪ **Backing: As a scientific background:** **a-** Pacinian Corpuscles are mechanoreceptors located in the skin and some internal organs. They detect deep pressure and vibration. When their membrane is deformed, ion channels open, leading to depolarization and the generation of action potential, these signals travel via sensory neurons to the brain. Oscilloscopes help visualize these electrical signals by displaying voltage changes over time. ▪ **Rebuttal**: other structures might cause the action potential seen on the oscilloscope. The action potential only appears when the Pacinian Corpuscle is stimulated. If a different tissue is tested or no pressure is applied no signals are produced. This shows the signals are directly linked to the Pacinian Corpuscle's response to mechanical pressure.
4. Group Activity:	The group activity is grouping the class into pairs and every student will ask his/her partner technical questions about the action potential of the neuron.

5. Allocated time 50-60 minutes (explanation) , 20 minutes for group work and discussion.

Stage 5: The Production of a Final Written Argument

Time: 50-60 minutes

1. **Final Argument Writing:**
   - Each student writes an individual final argument, using the Toulmin framework to organize their thoughts.
   - Students should answer the following questions:
     - **Claim**: based on the experiment that you did with your friends, what can you conclude about the relationship between the invertebrate decentral nervous system and the advanced nervous system?
     - **Relevant evidence:** rely on your research, poster, teacher support to formulate a solid evidence.
     - **A supported warrant: can we say,** "Decentralized control allows for faster local responses without needing a central processor"? how this statement support the claim.
     - **Backing from scientific principles:** What is your background information about other factors for the transmission of messages will play an extremely important role in this argument.
     - **Rebuttal:** Do the students search for external factors that may delay the message propagation?
2. **Writing Prompt:**
   - Provide students with a prompt to guide their writing.

     1. *The teacher will motivate her students to write a scientific argumentative paper that starts with the research question.*
     2. *The teacher also will ask the students to support their claim with evidence from the data and explain why the evidence supports their conclusion.*
     3. *The teacher will allow the students also to consider any counterarguments or conflicting evidence and address them in their argument.*
     4. *The students are provided with rubrics and due dated of submission via email on the school platform.*

3. **Submission:** Grading will be based on the rubrics and on the sharp submission date.

Extension/Reflection (60 minutes)	
Reason:	*This part encourages students to reflect on the lesson and extend their learning. It might include homework, further reading, or a reflection on how the argumentative skills learned can apply to other areas of science or life.* *After the lesson, the teacher reflects on how effectively students engaged in the inquiry and argumentation process. Were students able to use evidence effectively to support their claims? Did they engage in meaningful critique of their peers' arguments? What improvements can be made for future lessons?* **Procedure:** **A- The teacher designed a questionnaire that the student will receive and answer it individually.** **B- The teacher may have an online virtual game that will help the students to challenge as two groups to test the student knowledge.** **C- The teacher may ask the students to write suggestions to write their feedback and reviews about their new experience in explain based on argumentation.**

Stage 2: The Generation of a Tentative Argument (3 hours- 180 minutes)

Group Work: Every group will have a shared task to achieve building an analogy between the nervous system of the shrimp and coding system of robotics.

1. Each group is provided with a printed document having graphs of the action potential that are read on the oscilloscope.
2. Students use the Toulmin framework to develop a tentative argument:

- **Claim: the question will be asked:** How the decentralized nervous system is more efficient than the centralized nervous system?
- **Evidence:**
    i. The student will start to search for the difference of the nervous system of the shrimp (decentralized nervous system with distributed ganglia along the shrimp's body) and the centralized nervous system as such for the man or the birds that are all connected to the central nervous system.
    ii. **Research Observation:** the electrical activities that are generated across the neurons. The printables have graphs that the student search for them to ease the discussion among the students.
- **Warrant:** here the students will ask themselves why this experiment is related to analogy. Students will start their analogy by making the relation of every part of the nervous system to that in the coding system based on what they know and what they searched for.

Shrimp Nervous System	Robotic System
Ganglion	Microcontroller
Receptor (e.g., touch)	Sensor input
Action potential	Signal pulse
Oscilloscope	Debugger / serial monitor
Impulse to tail	Actuator response

- **Backing: Scientific principle:** the students studied the human nervous system and how this nervous system responds to the different stimuli that arise from the environment. The relation of what they studied in the computer class and the biology class will make it easier to understand the importance of the order of the parts of the nervous system and the position of the sensors that are located after each other on the spinal cord of the shrimp.
- **Rebuttal:** the fast responses that come from the decentralized system don't change this experience into memories like the central nervous system.

Teacher Support: In this activity, the teacher plays a central role in guiding, facilitating, and supporting student learning. The teacher begins by setting the context with engaging visuals or animations of the shrimp's nervous system and oscilloscope readings, then introduces a robotics analogy to spark curiosity. During the Kagan group work (e.g., Round Robin and Numbered Heads Together), the teacher ensures equal participation, prompts discussions with guiding questions, and supports students who struggle to articulate their ideas. As students match biological and robotic components, the teacher clarifies complex terms like "ganglia" and "microcontroller" and encourages deeper thinking by connecting functions across the systems. While constructing arguments using the Toulmin model, the teacher offers scaffolding, models strong responses, and provides formative feedback on claims, evidence, and rebuttals. During the graph analysis phase, the teacher explains how to interpret oscilloscope readings, helps students trace neural impulses, and poses critical thinking questions about delays and patterns. Throughout the lesson, the teacher fosters a reflective environment, encourages students to present and defend their ideas, and highlights the value of both scientific reasoning and interdisciplinary creativity.

Stage 3: The Argumentation Session (60 minutes)

1. Presentation Format:
- The student will create their own poster to present in the class. This poster will include all what the students researched and what they studied with their teachers besides all the graph analysis.

2. Peer Evaluation:
- As students present their arguments, others listen and provide constructive feedback based on the Toulmin model.
- The teacher can ask critical questions to encourage evaluation of evidence and reasoning (e.g., "Does this evidence fully support the claim?" or "What alternative explanations can you consider?").

3. Revision of Arguments:

After the argumentation session, students return to their original groups and modify their tentative arguments based on peer feedback.

Stage 4: A Reflective Discussion

Time: 50-60 minutes

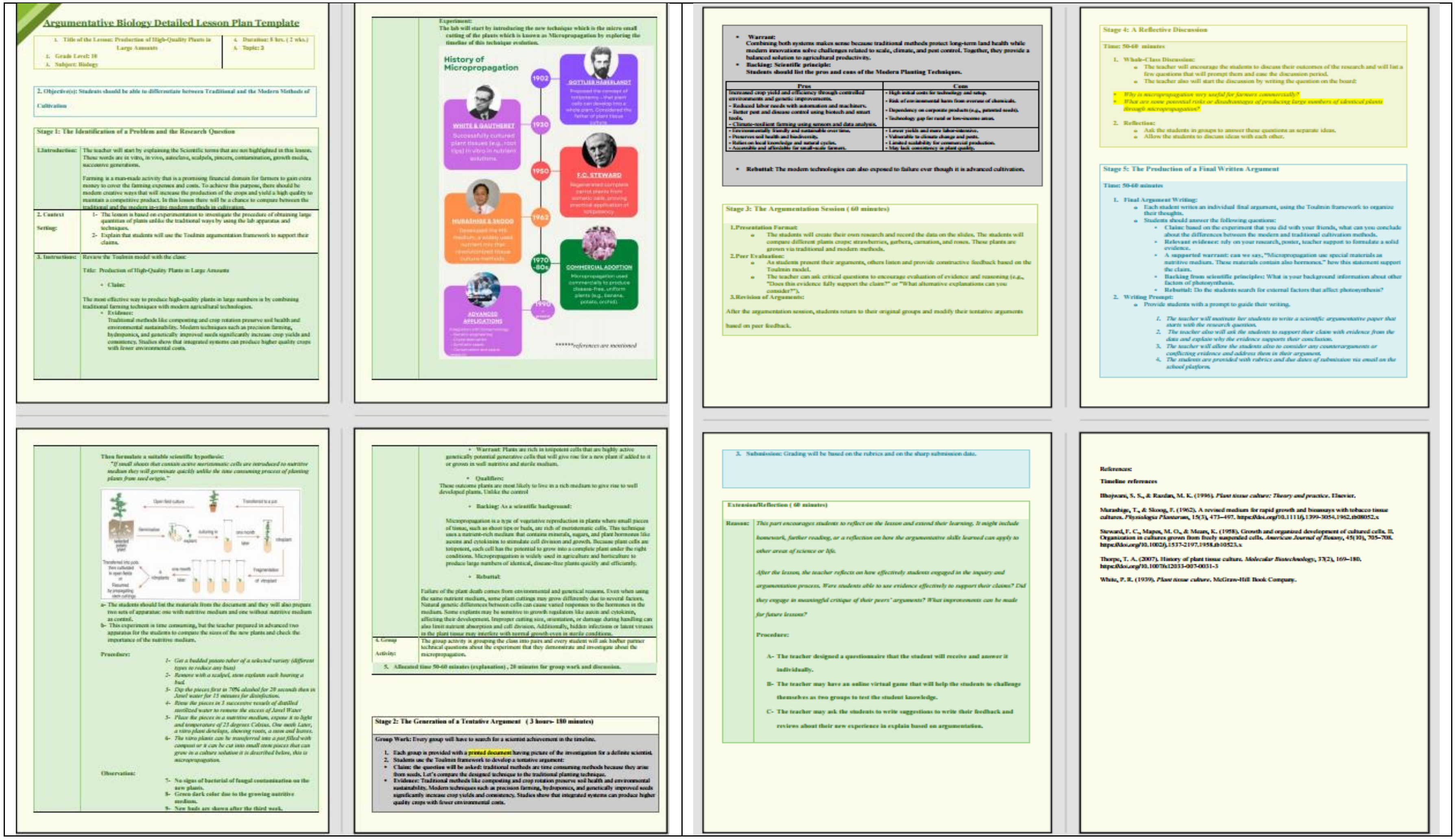
1. **Whole-Class Discussion:**
    - The teacher will encourage the students to discuss respectively their outcomes of the analogy and will list a few questions that will prompt them and ease the discussion period.
    - The teacher also will start the discussion by writing the question on the board:

- ***What did you learn about how nervous systems control movement and respond to stimuli?***
- ***How did argumentation help you better understand the differences between decentralized and centralized control systems?***
- ***What challenges did you face while analyzing the oscilloscope graphs, and how did the teacher's support or peer discussions help you overcome them?***
- ***If you were to improve your poster, what part would you clarify or strengthen? Why?***

2. **Reflection:**
    - Ask the students in groups to answer these questions as separate ideas.
    - Allow the students to discuss ideas with each other.

APPENDIX 3

LESSON PLAN 3: PRODUCTION OF HIGH-QUALITY PLANTS IN LARGE AMOUNTS



APPENDIX 4

LESSONPLAN 4: GREENHOUSE CULTURES

Argumentative Biology Detailed Lesson Plan Template

1. Title of the Lesson: Greenhouse Cultures 2. Grade Level: 10 3. Subject: Biology	4. Duration: 8 hrs. (2 wks.) 5. Topic: 4

2. Objective(s): students must indicate the importance of the limiting factors that involve in the green house plant culturing through argumentation and class activities.

Stage 1: The Identification of a Problem and the Research Question

1.Introduction:	The lesson discusses the greenhouse effect on the environment, particularly regarding the survival of plants and animals. These organisms have adapted to specific living conditions over the years, and most are not prepared to change their ways of life during dramatic environmental shifts. Human interference has created a serious imbalance in the life spans of these organisms, leading to new scenarios, including extinction due to deforestation, desertification, increased carbon footprints, global warming, and more. 1. The research question: How do environmental changes related to the greenhouse effect act as limiting factors that impact the survival, distribution, and reproduction of plant and animal species?
2. Context Setting:	1- Provide students with the data set or observations that they will use to address the research question such as exploring an article and case study about the weather changing in USA in May 2025 https://www.ncei.noaa.gov/news/national-climate-202505 2- Explain that students will use the Toulmin argumentation framework to support this research question by giving the students definite tasks that will accomplish at the end of this lesson
3. Instructions:	Review the Toulmin model with the class • Claim: Green houses are expecial cultures that help farmers to incubate their plants in optimum conditions and avoid any limiting factors to occur and thus to prevent the crop loss. • Evidence: Greenhouses are specially designed structures that create optimal growing conditions by controlling temperature, water, light, and humidity. This protection helps prevent common limiting factors such as frost, heat stress, drought, pests, and diseases, which typically reduce crop yields. For instance, drip irrigation systems in greenhouses ensure precise water delivery during dry periods, while controlled environments help reduce pest infestations. Additionally, technologies like supplemental lighting and humidity sensors maintain consistent growth conditions, resulting in more reliable and higher crop yields—sometimes up to 200% greater than those achieved through traditional farming. These advantages make greenhouses a vital tool for minimizing crop loss and supporting sustainable agriculture. Observation: a- After displaying pictures for the technically designed greenhouses, the students will suggest reasons of adding every single apparatus and relate it to the factors of photosynthesis • Warrant: Plants require specific environmental conditions—such as appropriate temperature, water availability, light intensity, and protection from pests—to grow healthily and yield well. When these conditions fall outside optimal ranges, they become limiting factors that hinder plant growth or lead to crop failure. Greenhouses address these issues by creating an ideal environment that minimizes or eliminates these natural limitations, ensuring better plant survival and productivity. • Backing: As a scientific background: a- The students already studied the factors that affect photosynthesis and its importance. The greenhouse comes as a solution to save these plants from extinction and provide a sustainable source for human beings particularly drought, weather changing and unfavorable life conditions. • Rebuttal: While greenhouses greatly reduce many limiting factors, their high construction and maintenance costs can make them less accessible to small-scale or resource-limited farmers. Furthermore, greenhouses may not fully derive natural environmental interactions, such as insect pollination or the presence of beneficial soil microbes, both of which are crucial for plant health and biodiversity. Lastly, improper management of greenhouses can lead to problems like overheating or disease accumulation, introducing new challenges for crop production besides lack of adaptability to the adverse environmental conditions for plants.
4. Group Activity:	Divide the students into small groups (3-4 students per group) to begin the inquiry activity. The activity is in the form of printable paper have a question out of three to answer: • *How does greenhouse design help control environmental factors such as temperature, humidity, and light, and why are these controls crucial for plant growth?* • *What roles do devices like irrigation systems, ventilation fans, and grow lights play inside a greenhouse, and how do they help prevent limiting factors?* • *How do crops grown in greenhouses differ from those grown in open fields regarding growth rate, yield, and protection from environmental stresses? What are some advantages and disadvantages of each method?* **In pairs, discuss by using your prior knowledge to what they studied. Students will use graphs and pictures that are attached to the question to refer to them while answering.**

5. Allocated time 50-60 minutes (explanation) , 20 minutes for group work and discussion.

Stage 2: The Generation of a Tentative Argument (3 hours- 180 minutes)

Group Work:

Every group will investigate botanical experiment "Investigating CO2 as a limiting Factor for photosynthesis in the Greenhouse Culture"

1. Each group is provided with a printed document
2. Students use the Toulmin framework to develop a tentative argument:
   Introduction:

A commercial tomato greenhouse in the UK conducted an experiment on carbon dioxide enrichment. Over a period of four weeks, one section of the greenhouse was exposed to normal atmospheric CO_2 levels (approximately 0.04%), while another section received enriched CO_2 levels (around 0.12%). All other conditions, such as light, water, and temperature, were kept constant.

The results revealed that the plants in the CO_2-enriched section grew taller, developed more leaves, and produced 30% more fruit compared to those in normal air.

- **Claim:** Increasing CO_2 levels in greenhouses improves plant growth and yield because CO_2 is a limiting factor in photosynthesis. What conclusion can you draw from this introduction?
- **Evidence:** Use the data and the results to collect the evidence that you build your claim on them.
- **Warrant:** Why does the evidence support the claim? You can list a scientific principle.
- **Backing:** based on what you studied about the factors of photosynthesis, write down the extra facts that support the optimum conditions of the green plant inside the green house and how these factors will become limited ones and the effects of this shortage.
- **Rebuttal:** The limited plant growth is not only related to the shortage of carbon dioxide. Other factors too besides hormones and fertilizers can limit plant growth.
- **Teacher Support:**

1. The teacher will guide the students to design two greenhouses: one with all the optimum conditions and the other with a missing limiting factor.
2. The teacher will approach the groups and support by listening to their arguments and motivate them by prompting and questioning to lead them to the conclusion easier.
3. The teacher will give 5 min to read the introduction and then allow them for 15 min to write the answers of the argumentation parts to present them to the class in stage 3.

Stage 3: The Argumentation Session (60 minutes)

1.Presentation Format:
- In a round-robin format, one member of each group stays at their workstation to present their argument while other students rotate to different groups to critique the arguments.

2.Peer Evaluation:
- As students present their arguments, others listen and provide constructive feedback based on the Toulmin model.
- The teacher can ask critical questions to encourage evaluation of evidence and reasoning (e.g., "Does this evidence fully support the claim?" or "What alternative explanations can you consider?").

3.Revision of Arguments:

After the argumentation session, students return to their original groups and modify their tentative arguments based on peer feedback.

Stage 4: A Reflective Discussion

Time: 50-60 minutes

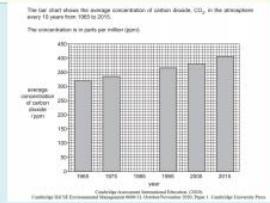
1. **Whole-Class Discussion:**
   - The teacher will use the white board to stick the diagrams of the technology of the green house such as the computerized sensors and Arduinos, the pH indicators and the digital barometers, thermometers and hydrometers.
   - The teacher also will start the discussion by writing the question on the board:

     When does a basic essential factor is considered as a limiting factor?
2. **Reflection:**
   - Ask the students in groups to answer these questions as separate ideas.
   - Allow the students to discuss ideas with each other.

Stage 5: The Production of a Final Written Argument

Time: 50-60 minutes

- **Final Argument Writing:**
  - Each student writes an individual final argument, using the Toulmin framework to organize their thoughts.
  - Students should answer the following questions based on this graph that relates how carbon dioxide can increase the greenhouse phenomenon in nature and what are the causes as well.



- **Claim:** The steady increase of the concentration of carbon dioxide in nature is presented in the graph due to many reasons such as the industrial revolution and the establishment of factories as well. List as much as possible the reasons for production and the emission of carbon dioxide.
- **Relevant evidence:** Do you agree that the trend of this graph is by 25 % per year?
- **A supported warrant:**

Carbon dioxide is a greenhouse gas that traps heat in the Earth's atmosphere. An increase in CO_2 leads to greater heat retention, contributing to global warming and climate shifts. The consistent rise in CO_2 levels illustrated in the graph supports the connection between human activities, such as burning fossil fuels, and the intensification of the greenhouse effect.

- **Backing on scientific principles:**

1. Climate science (IPCC, NASA) identifies CO_2 as one of the main gases driving enhanced warming.
2. While low CO_2 levels can restrict photosynthesis rates, excessive CO_2 can cause ecosystem imbalances and contribute to warming.
3. The timeframe illustrated corresponds with a rise in industrialization and vehicle emissions globally.

- **Rebuttal:** Carbon dioxide emissions may also be resulted from volcanic eruptions or natural burnings and not always from human activities.
- **Writing Prompt:**
  - Provide students with a prompt to guide their writing.

1. *The teacher will motivate her students to write a scientific argumentative paper that starts with the research question.*
2. *The teacher also will ask the students to support their claim with evidence from the data and explain why the evidence supports their conclusion.*
3. *The teacher will allow the students also to consider any counterarguments or conflicting evidence and address them in their argument.*
4. *The students are provided with rubrics and due dated of submission via email on the school platform.*

- Submission: Grading will be based on the rubrics and on the sharp submission date.

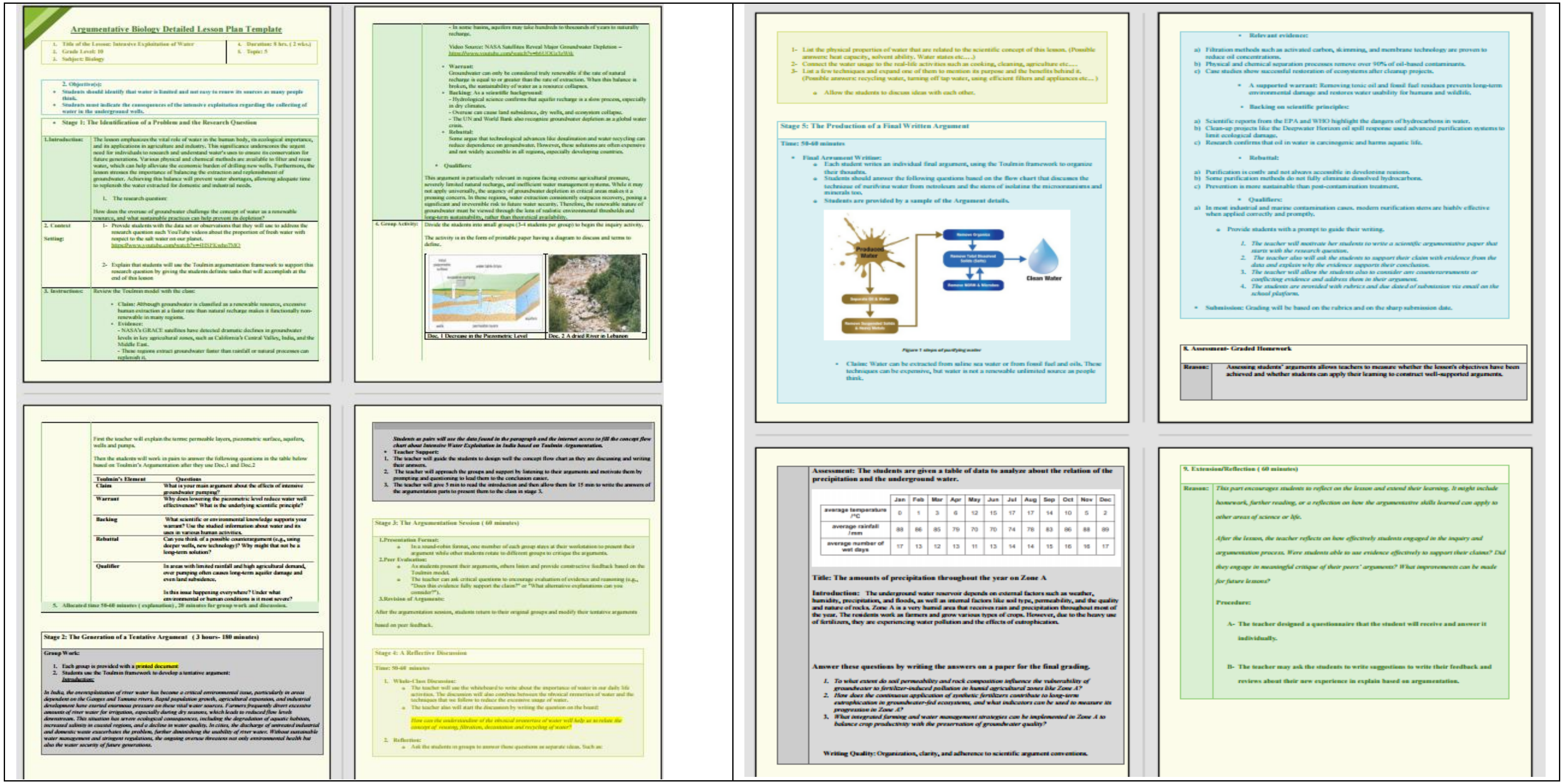
8. Assessment- Graded Homework

Reason:	Assessing students' arguments allows teachers to measure whether the lesson's objectives have been achieved and whether students can apply their learning to construct well-supported arguments. **Assessment: the students are given a real case study to explore.**  The forests in Denmark are managed to promote biodiversity **Title: The Effect of Deforestation and Greenhouse Effect on Nature.** **Introduction:** The forests in the Netherlands, especially in areas like the Veluwe and Utrechtse Heuvelrug, are managed forests. This means they are regularly thinned or partially harvested to promote biodiversity, reduce fire risk, and support local timber production. However, concerns are increasing about the environmental trade-offs of managed logging, particularly in the context of climate change and the greenhouse effect. **Answer these questions by writing the answers on a paper for the final grading.** • How does cutting down trees contribute to the greenhouse effect? • Is managed logging always sustainable? What practices might make it more climate-friendly? • Can biodiversity goals and climate protection go hand in hand in forest management? Writing Quality: Organization, clarity, and adherence to scientific argument conventions.

9. Extension/Reflection (60 minutes)

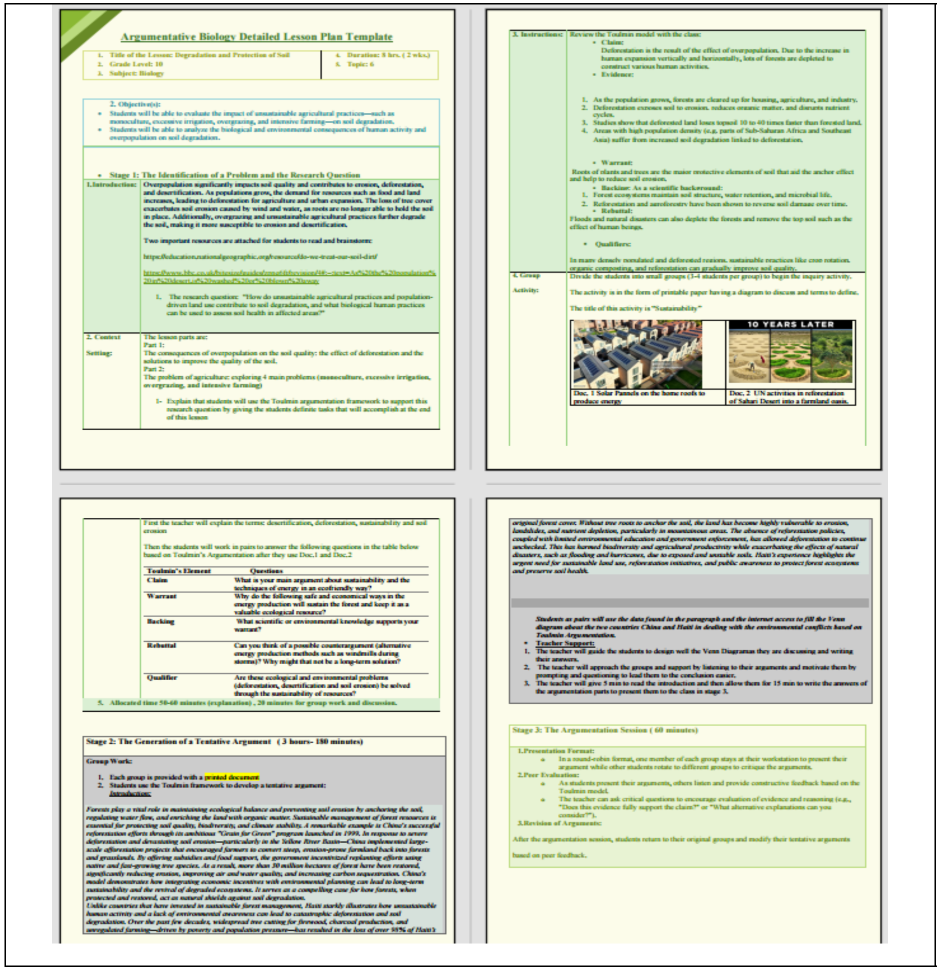
Reason:	*This part encourages students to reflect on the lesson and extend their learning. It might include homework, further reading, or a reflection on how the argumentative skills learned can apply to other areas of science or life.* *After the lesson, the teacher reflects on how effectively students engaged in the inquiry and argumentation process. Were students able to use evidence effectively to support their claims? Did they engage in meaningful critique of their peers' arguments? What improvements can be made for future lessons?* **Procedure:** **A- The teacher designed a questionnaire that the student will receive and answer it individually.** **B- The teacher may ask the students to write suggestions to write their feedback and reviews about their new experience in explain based on argumentation.**

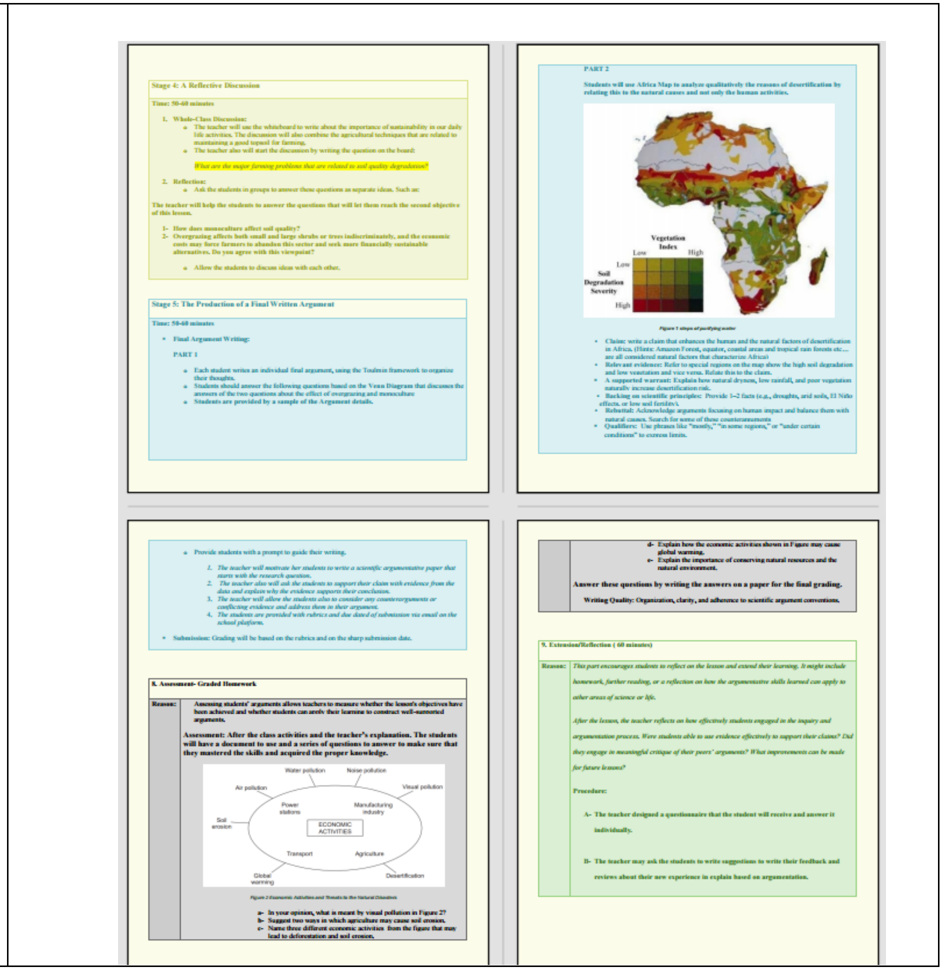
APPENDIX 5
LESSON PLAN 5: INTENSIVE EXPLOITATION OF WATER



Argumentative Biology Detailed Lesson Plan Template

APPENDIX 6
LESSON PLAN 6: DEGRADATION AND PROTECTION OF SOIL





APPENDIX 7
LESSON 1 FROM GRADE 10 BIOLOGY BOOK

ACTIVITY 3

THE USE OF THE SYNTHESIZED SUBSTANCES

The elaborated sap translocated by the phloem ensures the nutrition of the plant. What is the use of the organic materials in the cells ?

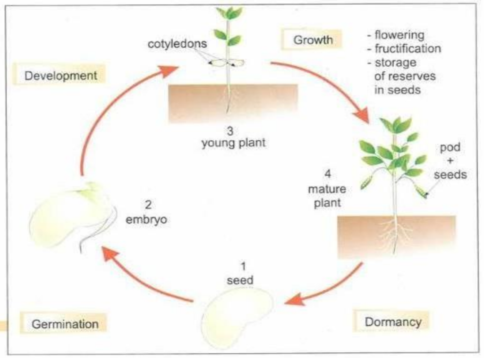
1 The storage of the organic materials

Certain plant organs are full of various nutritive substances :
- **carbohydrates:** starch in potatoes, sucrose in sugar beets, glucose in grapes
- **proteins:** in wheat, corn, beans.
- **lipids:** in olives, corn, peanuts.

These reserves are stored for later use by the plant.
The stored reserves constitute a great part of man's and animal's nutrition.

2 The use of the organic materials

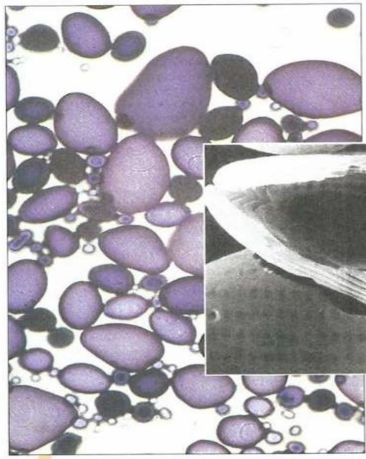
The cells use a part of the synthesized organic materials for nutrition and for building up new molecules of the cytoplasm. This ensures the growth of the plant.
A long term use of the materials that are stored in the reserve organs ensure the development of the plant.
Glucose is a source of energy used by all cells. Its oxidation produces the necessary energy for cell activities.



Doc. a
Life cycle of a bean

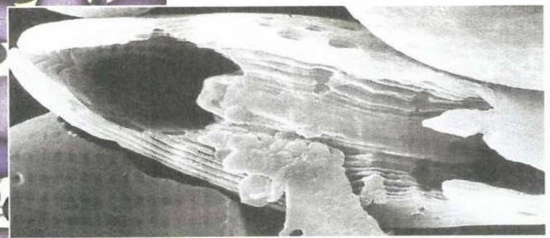
52

3 Consumption of reserves during plant development



Doc. b Starch grains observed under light microscope.

During germination, the reserves stored in the seed are consumed. The observation of starch grains in a germinating bean seed show that they are being hydrolyzed.



Doc. c A starch grain during hydrolysis observed by scanning electron microscope.

53

PROBING the ACTIVITY

1. How can the organic materials of reserves in the document of part 1, be identified?
2. After a sunny day, the presence of starch is identified in the leaves of a potato plant. How can then this starch reach the potato tubers?
3. How does glucose interfere in the synthesis of starch?
4. How is the protein contained in the organs of reserves synthesized?
5. During development the seed shows a decrease in its reserves. Formulate a hypothesis that explains this statement.
6. Does the comparison between the starch grains in docs.b and c make your hypothesis valid?
7. Why does the embryo need reserves?

APPENDIX 8
LESSON 2 FROM GRADE 10 BIOLOGY BOOK

ACTIVITY 6

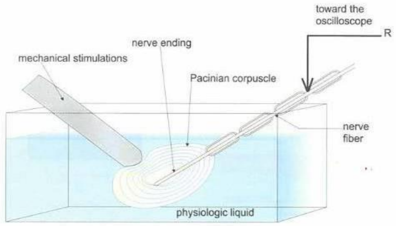
THE CODING AND THE TREATMENT OF THE NERVOUS INFORMATION

An afferent message reveals certain characteristics of a stimulus and conveys them to the nervous centers. The efferent message reveals signals of intensity of reaction. Are these two messages identical? How are they coded?

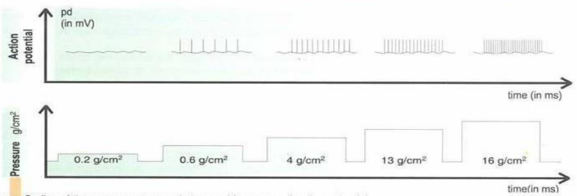
1 The coding of the nervous information

Pacinian corpuscles are sensory receptors found in the dermis of the skin and sensitive to pressure.

Apply a series of mechanical stimuli whose pressures are of different magnitudes, on the nerve ending. Place on its nerve fiber receptor electrodes connected to a recording system. The recorded results are summarized below.



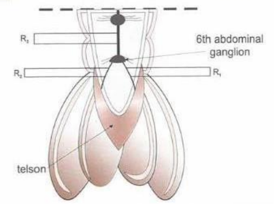
74



Doc. a Coding of the nervous message in terms of frequency of action potential

In a **fiber**, the appearance of action potentials (A.P) initiated increases in frequency with the increase in the intensity of stimuli. The series of action potentials per unit time will be received and treated by the nervous centers. In a **nerve**, the significance of this message depends on the number of fibers in action and on the activity of each fiber as well.

2 Treatment of nervous information

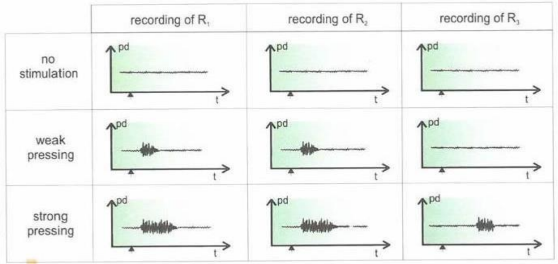


Upon touching the telson of a shrimp, the animal immediately starts a flight movement.

The telson is connected to the 6th abdominal ganglion by a pair of nerves.

Receptor electrodes: R_1, R_2, and R_3 are placed as indicated in the adjacent figure.

A series of excitations are applied on the telson and the recordings obtained are the following:



Doc. b Treatment of the coded nervous message by the nervous centers.

75

PROBING the ACTIVITY

1 Using doc. a, find the variable that changes with the intensity of the stimulus. What characterizes the amplitude of the action potentials? Compare the response of a nerve fiber(activity 5) to that of a nerve as a function of the intensity of stimulus.

2 Deduce from doc.b, the origin of the message recorded by R_1 and R_2. Where does the message recorded by R_3 reach? What is thus the role of the nervous centers?

3 The nervous centers are centers of treatment of the coded nervous messages. Analyze the recordings in doc.b and justify this hypothesis.

APPENDIX 10

LESSON 3 FROM BIOLOGY GRADE 10

ACTIVITY 3

PRODUCTION OF HIGH QUALITY PLANTS IN A LARGE NUMBER

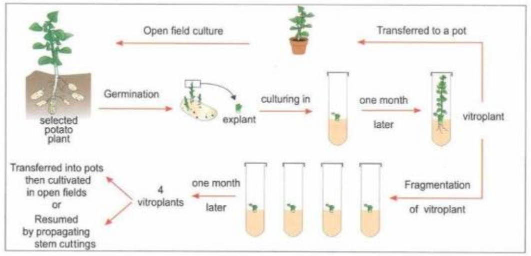
The traditional vegetative multiplication called propagation (cuttings, grafts,...) is widely used in plant cultures. This multiplication is improved by modern techniques of in vitro cultures. Those techniques consist of reproducing in a short period of time and in a large number plants that are similar to the parent plant. How are these cultures done?

1 Multiplication by small cuttings

Procedure

- Get a budded potato tuber of a selected variety.
- Remove, with a scalpel, stem explants each bearing a bud.
- Dip the pieces first in 70° alcohol for 20 seconds then in Javel water for 15 minutes for disinfection.
- Rinse the pieces in three successive vessels of distilled sterilized water to remove the excess of Javel water.
- Place the pieces in a nutritive medium, expose it to light and at a temperature of 23°C. One month later, a vitro plant develops, showing roots, a stem and leaves.
- The vitro plant can be transferred into a pot filled with compost or it can be cut into small stem pieces that can be grown in a culture solution as it is described below; this is micro-propagation.

106



2 Culture media

The culture media are available in the powder form to be dissolved in distilled water. They contain mineral substances, sucrose, and growth hormones.
These media are prepared two days before using them by following the instructions indicated by the manufacturers. Then they are put in the refrigerator in culture flasks that are previously sterilized and tightly closed.

3 Conditions of asepsis

1. Work on a clean table.
2. Wash your hands then rinse them with alcohol.
3. Sterilize the utensils (flasks, test tubes, scalpels, pincers ...) in an autoclave or in a pressure cooker at 110° C for 30 minutes.
4. Work close to a flame of Bunsen burner.
5. Pass the flasks' openings over the flame each time you open and close the flask.
6. Work rapidly to avoid the dryness and the contamination of the container.

4 Chain production

Doc. a Millions of identical saintpaulia obtained each year by small cuttings

cultivated plant	culture in vitro "small cuttings"	traditional multiplication
strawberries	50.000	50
rose	200.000 to 400.000	20 - 50
gerbera	400.000	50
carnation	200.000	200

Doc. b Descendants obtained per year by traditional vegetative multiplication and in vitro culture.

107

PROBING the ACTIVITY

1. What is the purpose of in vitro cultures?
2. Identify the way of plant reproduction in the in vitro cultures.
3. If an explant of a potato tuber aged one month develops four buds, calculate the theoretical number of cuttings that can be obtained from this piece after ten months.
4. Make an in vitro culture of a potato tuber, a saintpaulia or another plant.

APPENDIX 9
LESSON 4 FROM BIOLOGY GRADE 10

ACTIVITY 4

GREENHOUSE CULTURES

Field cultures are limited by the environmental factors. Nowadays, farmers resort more and more to greenhouse cultures to optimize the productivity. What factors do farmers act on?

Greenhouse cultures or cultures in tunnels under plastic allow the control of the amount of carbon dioxide absorbed, irrigation and temperature. The rise in temperature under the covers, known as the greenhouse effect is due to the partial retention of infrared radiation. This creates a microclimate that allows the production of flowers, fruits, and vegetables throughout the year.

Doc. a Strawberry cultures in tunnels under plastic.

Doc. c Tomato culture in a greenhouse

mass of fruits in Kg. m^{2}		
field culture	greenhouse culture	off-soil culture
6	10.5	14

Doc. b Comparing the productivity of three types of cultures developing in the same nutritive medium

PROBING the ACTIVITY

1 Analyze and interpret the results of doc.b.

2 Carbon fume is used in greenhouses to enrich its environment with carbon dioxide. Suggest a reason for this practice.

3 What is the origin and the role of water vapor that condenses on the internal wall of the greenhouse?

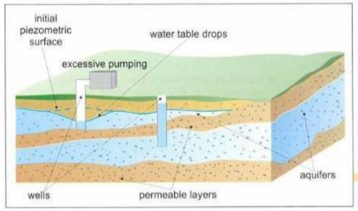
APPENDIX 10
LESSON 5 FROM BIOLOGY GRADE 10

ACTIVITY 5

INTENSIVE EXPLOITATION OF WATER

Even though water is a renewable resource, it is wrong to think that it is an unlimited resource. When exploitation of the water table is faster than its natural recharge, the piezometric level drops. How can the equilibrium of a water table be conserved?

1 Effect of intensive pumping of a water table



At equilibrium, each time water is pumped from a well in an aquifer, more water moves through the well hole keeping the piezometric level constant. When this level drops drastically, disequilibrium occurs in the water table. This is over exploitation.

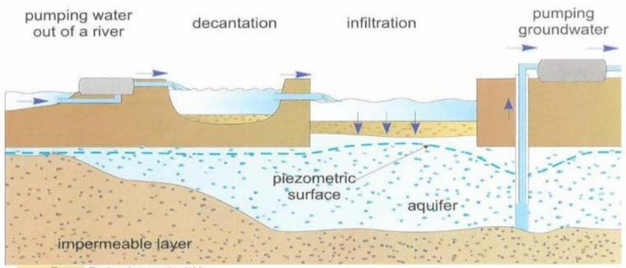
Doc. a Decrease of the piezometric level

160

Rivers originate from underground water springs. When underground water is over exploited, the amount of water available in springs decreases. As a result the quantity of water flowing in a river is reduced especially during non rainy seasons. A good water management is necessary to conserve it. Accordingly, artificial reservoirs are constructed to store water that can be used during drought seasons.

Doc. b A dried river

2 The artificial recharge of a water table



Doc. c Recharging a water table

Sometimes a water table in disequilibrium can be artificially recharged with water from another source. Recharging stations pump water either from an unexploited source such as a river or an unexploited water table to the table in disequilibrium.

The water extracted is subjected to decantation in shallow basins, then slowly infiltrates into the soil. Thus water free from pollution joins the aquifer in disequilibrium.

161

PROBING the ACTIVITY

1 Modernization of domestic machinery, industrialization, and agricultural progress improve the life style of man and increase the production but they require an increased water demand. What problem may be faced in the future? How can we avoid this problem?

2 Why does the water injected artificially into an aquifer must be decanted and slowly infiltrated before it joins the underground water table?

3 What is the effect of the over exploitation of a water table on a river especially if this river irrigates agricultural plains?

APPENDIX 11
LESSON 6 FROM BIOLOGY GRADE 10

ACTIVITY 6
DEGRADATION AND PROTECTION OF SOIL

The increase in the world's population has led man to increase the inhabitable spaces and the cultivated surfaces. Man has thus occupied the ecosystems that are in natural equilibrium and participated with unfavorable climatic factors in the degradation of soil. What are the consequences of this degradation? How should man protect the soil?

1 Deforestation

The slopes of barren soil are exposed to erosion by rain and wind. This erosion deteriorates the soil and divests the parent rock. This leads to aridity and desertification.
* The necessity for finding new agricultural lands, the extension of urbanization zones and the increase in the industries using wood as a primary material (papers, carpentings,...) resulted in the overexploitation of the forests and excessive cutting of trees .

Doc. a Overexploitation of forests.

184

* Accidental or provoked fires extend along many hectares of surfaces per day in the world. Fires and cutting trees favor the erosion of humus horizons carried away by water runoffs. It increases the risk of landslides and decreases the water supply into water tables.

Doc. b
Forest fires

These risks can be avoided by:
* respecting forests
* reforestation
* planned urbanization
* a balanced policy to the occupation of soil

2 Agriculture

Monocultures
During winter, large surfaces are left unexploited for many months. The machines used in agriculture press the soil making it impermeable to water. Crop rotation and green fertilizers or winter cultures protect the soil from erosion and runoffs.

Intensive agriculture
The exportation of an important biomass prevents the renewal of the mineral substances in the soil which necessitates the addition of chemical fertilizers or humus.
Culturing plants in terraces along the slopes of mountains limits the effect of water runoff and inhibits the leaching of nitrates into the underground water.

Overgrazing
Sheep and goats eat the small plants and thus inhibit the renewal of vegetation leading to a rapid desertification.

Excessive irrigation of badly drained soil
In hot and dry countries, the salinity of soil increases due to the migration of the mineral ions towards the top layers by the evaporation of water. This salinization leads to the chemical and biological degradation of the soil (destruction of the microorganisms, increase of salinity...)

Doc. d
Cultures in terraces on Lebanese mountains

185

These effects can be reduced by:
- rigorous control of the quantity of water by micro-irrigation
- the use of biodegradable pesticides
- the drainage of cultivated fields

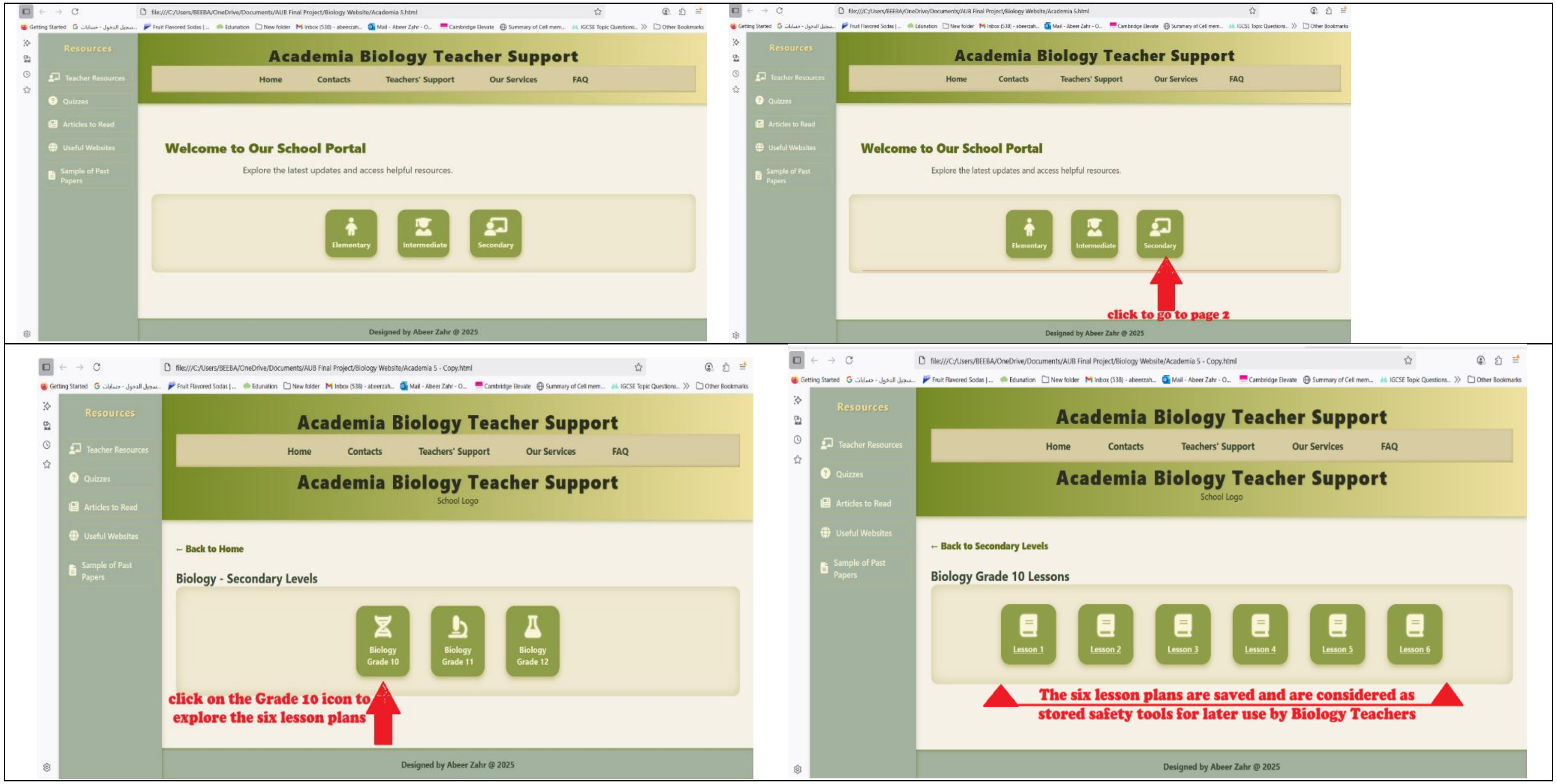
PROBING the ACTIVITY

1 What is the effect of the complete destruction of a forest found on a mountain slope?

2 What are the factors that have changed Lebanon from a "green country" to an arid country?

3 International organizations such as I.H.O. (International Health Organization) strongly refuse the use of many pesticides that are considered dangerous for health and for the environment. Make a research on the pesticides used in Lebanon (usage, origin, composition, effects on man and the environment).

APPENDIX 12
ACADEMIA WEBSITE (TEACHER PORTAL WEBSITE)



Page 1:

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