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Prospective Teachers' Levels of Scientific Literacy and Climate Change Awareness

By
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Dedication

This thesis took remarkable effort, energy and time, often at the expense of being with my loved ones. This thesis is dedicated to them; my husband and two daughters Serlie and Patil for loving, understanding and supporting me in pursuit of my education and career aspirations. You have been with me through all the steps, and seen me go through good and difficult times of completing this thesis. Thank you for being patient, supporting me, and helping me succeed.

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While this research study is the culmination of my hard work, however, it would have been impossible without the support of all the aforementioned people. Together we have a reason to rejoice!

Prospective Teachers’ Levels of Scientific Literacy and Climate Change Awareness

Marina Baltikian

ABSTRACT

Scientific literacy is a major goal of science education and is well reflected in K-12 science curricula and policy documents in many countries. Awareness of the adverse effects of climate change is important for public support and collective action towards mitigation and adaptation. Science teachers are major promoters of scientific literacy and climate change awareness and need to play an essential role in preparing scientifically literate students who are aware of the negative impacts of climate change. This study aimed to investigate the scientific literacy and climate change awareness levels of prospective teachers enrolled in teacher preparation programs at private universities in Lebanon. It also aimed to explore possible relationships between participants’ levels of scientific literacy and climate change awareness. The study adopted a mixed method approach. Quantitative data was collected from a sample of 30 prospective teachers using the Test of Basic Scientific Literacy Skills, and the Awareness Scale of Climate Change instruments. Qualitative data was collected through four semi-structured interviews. The findings of this study revealed that prospective teachers have low levels of scientific literacy, but a significant level of climate change awareness. The results showed that there are no significant differences in the levels of scientific literacy or climate change awareness of prospective teachers enrolled in different years at university. A weak negative correlation was also found between the levels of scientific literacy and climate change awareness. Although this study is limited to participants from two private universities in Lebanon, the findings raise new questions for future research. Recommendations are also provided for Departments of Education having teacher education programs.

Keywords: *Climate change; Science education; Science teacher education, Scientific literacy*

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AAAS	American Association for the Advancement of Science
ACARA	Australian Curriculum Assessment Reporting Authority
ACCQ	Awareness of Climate Change Questionnaire
ANOVA	Analysis of Variance
ASCC	Awareness Scale for Climate Change
BAT	Beliefs About Teaching
CAI	Climate Change Awareness Index
CCA	Climate Change Awareness
CCSDA	Climate Change and Sustainable Development Awareness
CMEC	Council of Ministers of Education Canada
CNRS	Council National for Scientific Research
CRDP	Center for Educational Research and Development
CSIRO	Commonwealth Scientific and Industrial Research Organization
FAO	Food and Agriculture Organization
FLRM	Forest and Landscape Restoration Mechanisms
IPCC	Intergovernmental Panel on Climate Change
ISTSST	Impact of Science and Technology on Society Subtest
LLTS	Lifelong Learning Tendency
MOE	Minister of Education
NAS	National Academy of Sciences
NGO	Non-Governmental Organization
NGSS	Next Generation Science Standards
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSST	Nature of Science Subtest
OECD	Organization for Economic Co-operation and Development
PISA	Program for International Student Assessment
PPMC	Pearson Product Moment Correlation
S^3PC^2Q	Secondary School Students’ Perception of Climate Change Questionnaire
SAI - II	Scientific Attitude Inventory
SCKS	Science Content Knowledge Subtest
SEL	Scale of Environmental Literacy
SFAA	Science for All Americans
SPSS	Statistical Package for Social Sciences
SSI	Socio-Scientific Issue
STEBI-B	Science Teaching Efficacy Belief Instrument
STS	Science Technology Society
TBSL	Test of Basic Scientific Literacy
TEP	Teacher Education Program
TOSLS	Test of Scientific Literacy Skill
TOSRA	Test of Science related attitudes
UNESCO	United Nation Educational, Scientific and Cultural Organization

Chapter I

Introduction

This study examines the scientific literacy levels and climate change awareness of prospective teachers in private universities in Lebanon. It also explores possible relationship between prospective teachers' levels of scientific literacy and climate change awareness.

For more than a decade, the world is faced with significant environmental problems, but recently climate change has become a substantial environmental issue worldwide (Debonne, 2019). Climate change has been a momentous topic of concern not only to scientists, but also heated debate at government level (Fagerberg, Laestadius, & Martin, 2016; Haines, 2003; McCarthy, Canziani, Leary, Dokken & White, 2001; Weingart, 2000; Whitmarsh, 2009). While climate change is one of the extensively covered topics by the mainstream media, its causes and consequences are complex and difficult for individuals to understand (Saribas, 2015). Herein, science education plays a crucial role in cultivating meaningful education to promote climate literate citizens (NOAA, 2009). Lopez and Malay (2019) argue that nurturing awareness and encouraging positive attitude about climate change should start at early years of formal education by dedicating a course related to climate change, and integrating environmental education in the K12 curricula.

Climate change is considered to be a complex environmental issue facing our planet (Byrne et al. 2014), yet underestimated and devalued in school curricula (Bardsley & Bardsley, 2007). This reveals a new challenge to science educators to increase climate change awareness of students which defines as accumulation of knowledge, attitudes or beliefs held by an individual on climate change and global warming - given the importance of increasing next generations' awareness of the impacts of climate change in their everyday lives (Lambert & Bliecher, 2017).

Climate change can be considered a socioscientific issue (SSI). Sadler and Zeidler (2003) defined socioscientific issues as inquiries, problems, questions, paradoxes, that students can engage with, as these issues have a conceptual basis in science, and emerge as ethical, political and economic arena of a society. Herman et al. (2018) elucidated socioscientific issues as ill-defined problems at the interface of science and other facets of the society. These issues are, in the researchers' words "controversial"; "multi-faceted"; prone to contradictory perspectives; and related to scientific concepts. According to Dawson (2015) climate change fulfils the criteria for socioscientific issue as the science behind it, is subject to change. Moreover, it is debatable in media and controversial in public discourse, as public views diverge when it comes to the science, causes and consequences involved.

There have been numerous studies reporting the positive impact of teaching socioscientific issues on student motivation and interest in learning science and pursuing science careers (Dori, Tal, & Tsaushu, 2003; Harris & Ratcliffe, 2005; Parchmann, Gräsel, Baer, Nentwig, Demuth, & Ralle 2006; Sadler, 2009). A number of scholars have indicated the effect of teaching socioscientific issues to foster students' critical thinking skills, decision making, argumentation, reflective judgement and moral development (Dawson, 2011; Eastwood, Schlegel, & Cook, 2011; Sadler, 2004, 2009; Zeidler, Applebaum, & Sadler, 2011; Zohar & Nemet, 2002). Furthermore, teaching socioscientific issues may contribute to foster scientific literacy of students (Zeidler, Sadler, Simmons, & Howes, 2005). According to OECD (2017) a scientifically literate person is able to participate in a reasoned discussion concerned with science-related and technology-related issues and scientific concepts, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry and interpret data and evidence scientifically. Sadler (2002, 2003) argues that one's ability to participate in debates regarding socioscientific issues, and making informed decisions regarding these issues, is at least one dimension of scientific literacy.

Roberts (2007) suggested two broad "visions"; Vision I and Vision II, to categorize the variety of ideas that encompass scientific literacy as a means of framing the outcomes of science education. Vision I, is concerned with the internally directed perspective of scientific literacy; the academic perspective of science. In particular, realization of Vision I scientific literacy necessitates that learners acquire the important understandings of content and competencies by the scientific disciplines regardless of the importance of the developed ideas and practices in other situations. Vision II relates to externally directed perspective of scientific literacy; science education developed for all citizens and encourages students to engage with the scientific ideas and practices in social setting; societal issues affected by scientific phenomena. Roberts describes scientific literacy as a continuum with Vision I and Vision II as opposite ends of this continuum, and socioscientific issues instruction as enhancement of the outcomes of both visions.

For more than a decade, the overarching goal of science education around the world has been promoting scientific literacy to prepare scientifically literate future citizens (American Association of Advancement of Science, [AAAS], 2014; Bybee, 2008; BouJaoude 2002; Councils of Ministers of Education, Canada, [CMEC], 1997; Miller, 2006; Ministry of Education in Taiwan, 2001; National Research Council [NRC], 2012; Zembylas, 2002). Different arenas, including the workforce, need scientifically literate people (National Research Council [NRC], 2012), who understand the importance of nature of science, and science and technology on the advancement of the society (Altun-Yalcin, Acisli & Turgut, 2011; Cavas, P., Ozdem, Cavas, B., Cakiroglu & Ertepinar, 2013; Chin, 2005; Ozdemir, 2010). Cultivating scientific literacy to prepare scientifically literate citizens also leads to economic growth and stability at political and social levels (Assareh & Bidokht, 2011). The citizen's culture is a key factor in determining his / her concerns, priorities, behavior, practices and scientific pillars (Al Shibani, 2000). Yacoubian (2018) elucidates the importance of scientific literacy teaching at schools, in order to engage the future citizens in informed decision-making on the personal and social levels. Norris and Phillips (2003) identify a scientifically literate person; through one's ability to distinguish science from non-science, the knowledge assimilated will help them participate in science-related social issues and ability to think critically about them. Moreover, Yacoubian (2018) argues that the scientific literacy can be achieved through well-developed science curriculum which embeds the principles of democratic education.

As 21^{st} century citizens, it is indispensable to be equipped with scientific literacy and knowledge to address global environmental and sustainable issues locally and globally (Yeoh, 2017). Having a scientifically literate society is essential, as comprehending and resolving various public related science issues, such as environmental issues, demand basic scientific background. Hence, every citizen should have a certain level of scientific literacy (Hazen & Trefil, 1991). In the public context, Dawson and Venville (2009) defined scientific literacy as the ability of an individual to understand science, participate in public discourse of socioscientific issues and make informed decisions related to these issues, as well as understand the processes, values and ethics related to science.

With scientific literacy as the main goal of science education, reform movements led to revised documents such as the National Science Education Standards (National Research Council [NRC], 2012). A curriculum reform was also initiated in some countries with the aim of improving the scientific literacy of the students (AAAS, 2014; Minister of Education in Taiwan, 2001; Ministry of National Education in Turkey, 2006). In line with science education's integral role, researchers have acknowledged the importance of fostering scientific literacy as early as possible (Barton, 1994; Bybee, 1997; Bybee & Fuchs, 2006, Lopez & Malay 2019). In this vein, science educators have made attempts to improve the quality of science education by refining the standards in schools, not only to benefit the individual societies but also to improve the quality of potential future teachers (Chin, 2005). The strength of science education and promoting students' scientific literacy depends on the competency of science teachers (Rubini, 2016). Therefore, investigating the level of scientific literacy of prospective teachers is critical because of the vital role that teachers play in promoting scientific literacy and preparing scientifically literate students (Al Sultan, Henson, & Fadde, 2018).

The consensus of science education to foster scientific literacy in students is disclosed in standards documents from the United States (American Association for the Advancement of Science, 1990); (National Research Council, 2012); Council of Ministers of Education Canada, 1997; Miller & Osborne, 1998; Queensland School Curriculum Council, 2001). Laughksch (2000) describes scientific literacy as a concept with diverse factors influencing the interpretation of this concept. According to Laughksch, these factors include variety of different interest groups that are inquisitive with scientific literacy, different conceptual definitions of the word, the nature of the scientific literacy, different purpose for promoting scientific literacy in the community and different ways of measuring it. Over the course of development of the concept, various positions, interpretations and definitions of scientific literacy have been suggested. Some of the proposed definitions were based on research, and others were based on personal views about the distinctive qualities of a scientifically literate person and what such an individual should be capable of doing (Laughksch, 2000).

In this vein, Al Sultan et al. (2018) studied the scientific literacy levels of elementary pre-service teachers. The results demonstrated that pre-service elementary teachers enrolled in advanced science methods course had satisfactory scientific literacy levels. Specifically, Advanced Science Methods course prospective teachers showed a positive relationship between scientific literacy and self-efficacy. Other studies compared the scientific literacy levels of prospective teachers in the first and fourth year of the teacher preparatory program and showed that at both levels prospective teachers showed borderline to low levels of scientific literacy, and hence needed improvement (Cavas et al. 2013; Karamustafaoglu et al., 2013). Within the same line, other studies investigated the scientific literacy of prospective teachers throughout their four-year teacher preparation program and the results demonstrated that highest scientific literacy level of prospective teachers was during their final year (Altun-Yalcin et al., 2011; Ozdemir 2010). Altun-Yalcin et al. (2011) highlighted the fundamental role of teachers in promoting the scientific literacy of students in schools and society, as both teachers' subject matter knowledge and pedagogical knowledge are essential to effective science teaching and student understanding (Chan & Yung, 2018; Hattie, 2012).

Prospective teachers should also be well prepared to be able to address sustainability challenges such as climate change, loss of biodiversity, food scarcity and increasing population growth (Boon, 2016). One of the globally anticipated response to develop citizen's capability to take the initiative to mitigation and adaptation actions, to address climate change issue, is through teaching the concepts of climate change at all levels of formal (Anyanwu, Le Grange, & Beets, 2015) and informal science education (Hayden, Houwer, Frankfort, Rueter, Black, & Mortfield, 2011). However, a number of studies have shown that prospective teachers and students have misconceptions and misunderstandings regarding climate change (i.e. Karpudewan & chandrakesan, 2015; Manolas & Filho, 2011; Papadimitiou, 2004). Boon (2010) argues that these misconception and misunderstandings could be attributed to the complexity of the science involved. This vision, among other things requires teachers who have sufficient knowledge about the science of climate change to be able to deliver the conceptual understanding of this important environmental issue to students; the future citizens (Hestness, McDonald, Breslyn, McGinnis & Mouza, 2014; National Center for Science Education, 2012; United Nations Educational, Scientific and Cultural Organization (UNESCO), 2012).

Climate change is responsible for serious changes at the geological, ecological and biological levels, however, the public is only aware of the most publicized ones such as the melting of glaciers and dispersion or extinction of certain species (Dal, Ozturk, Alper, Sonmez & Cokelez, 2015). According to Parry et al. (2007) climate change is caused by human activities which led to a change in global atmospheric composition. At the national level, a report published by Lebanese Ministry of Environment, *Linkages between Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) in the Agriculture Sector* (Minister of Education [MoE], 2019), mentions the increased impact of climate change in Lebanon through various disasters; like floods, storms, heavy rainfall, heat waves, cold waves, wildfires, field and land erosion. The most affected by the negative impacts of climate change are the agricultural sub-sectors such as seasonal crops, fruit trees, greenhouses, forestry sector, animal sector and fishery sector, which experienced humongous economic losses (CNRS & FAO 2018). However, the majority of Lebanese population is unaware of climate change (Saab, 2009), despite climate change being experienced in the country (MoE, 2019). Nevertheless, according to the MoE report (2019) the Lebanese government is aware of and concerned about climate change as a development issue. In this regard, the government has developed different organizations and NGOs working on various projects which outlines specific measures to be taken to mitigate and build resilience to the negative impacts of climate change. Of these projects worth mentioning the Forest and Landscape Restoration Mechanisms (FLRM) which helped in restoring up to 1000 ha of grazing lands to reduce CO_2. However, the aspects of disaster risk reduction and climate change awareness remain marginal from these projects. Hence, schools are held accountable for preparing socially and environmentally responsible literate future citizens, as the world is facing environmental problems, and the solutions to these environmental issues are science-related (Burgess, Hamilton, Garrison, & Robbins; 2018). Fostering awareness has shown to be an efficient way to change behavior from passive to proactive (Henly-Shepard, Gray, & Cox, 2015; Chappin, Bijvoet, & Oei, 2017). In this regard, school teachers have an essential role in fostering the climate change awareness as educators at early stages of education. Therefore, it is essential for prospective teachers to possess adequate understanding related to climate change and climate change awareness in order to provide quality education related to climate change awareness, adaptation, and mitigation which will lead to appropriate behavioral responses by the future citizens (Ceyhan, & Mugaloglu, 2020; Dal et al., 2015; Eze, 2020).

Although studies have been conducted by scholars investigating the scientific literacy levels of prospective teachers or climate change awareness levels of prospective teachers, in particular, no study, to the researcher's knowledge, has considered to examine whether there is any relation between the scientific literacy levels of prospective teachers and their climate change awareness. However, some authors have investigated the relationship between the scientific literacy and environmental literacy - environmental literacy is defined as set of skills to comprehend and explain the relative health of the environmental systems and to enact the required action to maintain, restore and improve the health of the system Roth (1992, p. 5) - or environmental awareness – environmental awareness is defined as set of knowledge, critical reasoning, and standpoint related with environment which can be explained by the concepts of awareness, awareness that causes a change in the acknowledgement and understanding, which brings about a change in behavior, attitude and pro-environmental measures (Hadzigeorgiou & Skoumios, 2013). For example, Saribas (2015) investigated the relationship between pre-service teachers' scientific literacy levels and their environmental literacy. The findings of the study showed that the pre-service teachers' scientific literacy level is correlated with the four dimensions of environmental literacy; environmental knowledge, environmental attitude, perception of environmental uses, and environmental concern. Ozturk (2018), using the PISA 2015 results, tried to investigate the contribution of environmental awareness and environmental optimism on students' scientific literacy levels. The study provided evidence that there is a significant relationship between these two environmental-literacy related factors and scientific literacy levels of students. Moreover, some researchers tried to show the relation between scientific literacy levels and; environmental literacy, climate views, socioscientific issues (Saribas, 2015; Corner 2012; Kosto, 2001).

1.1 Context and Statement of the Problem

In 2015, Lebanon participated for the first time, in the Program for International Student Assessment (PISA), directed by the Organization for Economic Co-operation and Development (OECD). Around 540 000 students, from 72 countries participated in PISA 2015 (OECD, 2016). OECD (2016) document elaborates the objective behind PISA assessment of 15-year old students, as "PISA assesses not only whether students can reproduce knowledge, but also whether they can extrapolate from what they have learned and apply their knowledge in new situations. It emphasizes the mastery of processes, the understanding of concepts, and the ability to function in various types of situations" (OECD, 2016, p. 11). PISA 2015 specifically focused on the scientific literacy of 15-year-old students, to measure their achievement level and compare how well they are prepared to meet the real-life challenges with the knowledge and skills acquired through schooling. The results showed that Lebanese 15-year old boys scored 381 points, while the 15-year-old girls scored 386 in science compared to an average of 489 points in other countries. Lebanon occupied the 58th place from 72 countries participating (Gurria, 2016). The difference between Lebanon's mean score in scientific literacy and that of the OECD mean average score is 107 (PISA National Report, CERD, p. 10). Lebanon's mean average score in PISA was below proficiency level 2 (PISA National Report, CERD, p. 71), significantly lower than the OECD average, the PISA mean average score also provides important comparative perspectives regarding the education systems, instructional approaches, strategies and background data regarding the students, teachers and schools. Therefore, it will be important to identify the contributors to scientific literacy, in order to help in identifying possible ways to address this issue. One way is through assessing the scientific literacy levels of prospective teachers to shed light if they enter their career with a significant level of scientific literacy.

In his research, Singh (2016) mentions that even with clear measures established to mitigate climate change, there is a need to educate people on the negative impacts of climate change. Hence, increasing awareness on climate change through education by integrating the concept in school curriculum and explicitly teaching the concept will help preparing the students; the future citizens to play an active role in mitigating and adapting to climate change. Singh calls out to the importance of assessing the teachers' level of awareness on climate change as studies have shown teachers' level of awareness is likely to influence their teaching and transferring the climate change knowledge in the classroom.

As far as the researcher knows, there is no previous research studies to have attempted to assess the level of climate change awareness among Lebanese prospective teachers.

The "Introduction" and "Context of Problem" sections of this Masters' thesis highlight the scarcity of previous research regarding the scientific literacy levels of prospective teachers in Lebanon. Moreover, previous research failed to explore the prospective teachers' climate change awareness in the Lebanese context, and the short time spent on these topics during instructions have all given rise to the purpose of this research study.

1.2 Purpose of the Study

The purpose of this study is to examine the levels of scientific literacy and climate change awareness of prospective teachers in private universities in Lebanon and to explore the relationship between their levels of scientific literacy and climate change awareness.

1.3 Research Questions

The study will be conducted with the following research questions in mind:

a. What are the scientific literacy levels of prospective teachers in private universities in Lebanon?

b. What are the climate change awareness levels of prospective teachers in private universities in Lebanon?

c. What relation exists, if any, between Lebanese prospective teachers' levels of scientific literacy and climate change awareness?

1.4 Definition of terms

For the purpose of this study, three terms need to be defined, which are scientific literacy, climate change and climate change awareness.

1.4.1 Definition of scientific literacy

In this study, scientific literacy is defined as one's ability to participate with science-related matters and concepts of science as a reflective citizen (OECD, 2017). According to OECD (2017) a scientifically literate person is able to participate in a reasoned discussion concerned with science-related and technology-related issues and scientific concepts, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry and interpret data and evidence scientifically.

1.4.2 Definition of climate change

The definition of the climate change follows the definition of the Australian Academy of Science (Allison, 2015), as transformation in the regular pattern of climate, which may be due to a combination of natural and anthropogenic (caused by human activity) causes, over a long period of time.

1.4.3 Definition of climate change awareness

The climate change awareness, in this study, is based on the definition of Oruonye (2011), which defines as accumulation of knowledge, attitudes and beliefs held by an individual on climate change and global warming.

1.5 Rationale of the Study

The focus of this research is on prospective teachers, as these are the future teachers who are entrusted with the responsibility to prepare scientifically literate students at early stages of formal education. With the rapid population growth and consequently increase in anthropogenic influences on nature, students need to be prepared to cope with the negative impacts of climate change for human, animals and plants. Hence, students should be aware of the negative impacts of climate change at a young age in order to hopefully develop positive influence on their environmental behavior and adopt mitigation and adaptation aptitudes as future citizens.

First, despite an increased interest in scientific literacy, it is surprising that few studies have investigated the scientific literacy levels of people who are engaged with science (Altun-Yalcin et al., 2011; Ozdem 2009). There are few studies related to prospective teachers' scientific literacy levels, which have relied on quantitative analysis to measure the scientific literacy level of prospective teachers (Altun-Yalcin et al., 2011; Bacanak & Gokdere, 2009; Cavas et al., 2013; Chin, 2005;

Karamustafaoglu et al., 2013; Ozdemir, 2010). In this vein, this study relies on mixed method research methodology to collect and analyze data.

In the Lebanese context, according to PISA 2018 report (OECD, 2018), Lebanon showed similar results to that of 2015 (first time Lebanon participates in PISA assessment), scoring lower than the OECD average in reading, math and science. The report pinpoints that only 38% of Lebanese students can provide possible explanations in a familiar scientific context and draw conclusions while the worldwide average is 78%. Considering the important role of primary school teachers from imparting knowledge to supporting students' learning styles, they are also accountable for preparing scientifically literate next generation. In this regard, it is essential to investigate whether prospective teachers have an adequate level of scientific literacy which, will help in nurturing their ability to teach science.

In this regard, the academic EBSCO*host* database of the Lebanese American University (LAU), Shamaa and google scholar were used by the researcher to identify Lebanese and international studies related to the elementary prospective science teachers' scientific literacy levels. Keywords included "Lebanese prospective teachers", "Lebanese prospective teachers' scientific literacy levels", "Lebanese in-service teachers", "Lebanese in-service teachers' scientific literacy levels". The databases showed a gap in literature, in the Lebanese context.

Second, literature review has indicated climate change as one of the most important environmental issues facing the world today. To diminish the negative effects of climate change there must be intervention strategies to withstand this issue. One of the strategies is to create awareness of climate change at schools. However, literature disclosed the misconceptions and misunderstandings of pre-service teachers about climate change (Dimitriou, 2002, 2003; Dove 1996; Groves &

Pugh, 1999; Groves & Pugh, 2002; Khalid, 2001, 2003; Papadimitriou, 2004; Summers, Kruger, Childs, & Mant, 2000) and their alternative conceptions (Groves and Pugh 2002; Papadimitriou, 2004). To investigate where the misconceptions, misunderstandings and alternative conceptions arise is beyond the scope of this study. Research has also revealed that family and teachers are the most influential people of children's pro-environmental behavior (Chawla, 2009; Duarte, Escario, & Sanagustín, 2017). Students need to be knowledgeable about climate change and how it will drastically affect their lives in order to enact pro-environment decisions and behaviors. Therefore, it is essential for teachers to possess solid understanding and awareness of climate change to be able to provide pedagogically sound learning experiences to their students from the earliest years of formal education. Prospective teachers play a vital role in importing knowledge of climate change but also in shaping pro-environment behavior and attitude of students. In this vein, gauging the level of climate change awareness of prospective teachers and keenness to act for pro-climate behavior is important, as teachers are responsible to raise awareness on climate change from early years of education in order for students to acquire the fundamental knowledge and skills in order to have appropriate behavioral response.

A closer look, in this regard, to the literature on climate change awareness of teachers and prospective teachers in the Lebanese context the academic EBSCO*host* database of Lebanese American University, Shamaa, and google scholar were searched. the following keywords "Lebanese prospective teachers' climate change awareness", "Lebanese teachers' climate change awareness", "Lebanese in-service teachers' climate change awareness" were used to check if in-service teachers' climate change awareness were examined. No study to date, to the researcher's knowledge, in the Lebanese context has examined the climate change awareness of prospective teachers. Herein, the importance of the second aim of this study to fill the gap in literature and contribute to the literature with a study in Lebanese context to determine the climate change awareness of prospective teachers.

Third, to explore the literature regarding studies, the academic EBSCO*host* database of LAU, Shamaa and google scholar were searched using the following keywords “scientific literacy and climate change awareness”, “climate change awareness and scientific literacy levels”, “scientific literacy levels and climate change awareness of teachers”, “scientific literacy levels and climate change awareness of pre-teachers”, “scientific literacy levels and climate change awareness of prospective teachers”. To the best of researcher’s knowledge, there seems to be a gap in the literature regarding the existing relation between the scientific literacy of prospective teachers and their climate change awareness levels. Hence, this research intends to try to investigate whether there is any relation between these two variables.

In light of these arguments and with an attempt to fill the gaps in the literature, the current study was initiated as part of a requirement of a master's thesis research project.

1.6 Significance of the Study

This study adds to the growing field of knowledge on scientific literacy and climate change awareness. The contribution of this thesis is fivefold. First, findings from this study will be used to show the scientific literacy and climate change awareness levels of prospective teachers in Lebanon. Moreover, it will provide insight into the extent, if any, of relationship between the scientific literacy and climate change awareness levels. In addition, it is hoped that this project will contribute to an ongoing body of research into the issue of climate change awareness at the national level.

Second; in terms of research, this study will enrich the literature as it sheds light on prospective teachers' awareness regarding the climate change issue, in the Lebanese context. Teachers should be aware and intentionally integrate climate change awareness in their teaching in order to foster pro-climate change awareness in students (Blackmore, Harrington, Letchford, & Martin 2018; Padmanabhan, Borthakur, & Mittal, 2017). The current and future generation will be drastically affected by climate change, and in order to halt the impact, the future citizens should change their lifestyles to minimize the carbon footprint. Further, most research regarding climate change has focused on the negative impacts, adaptation and mitigation actions, and to certain extent specific public perception. Studies regarding awareness of climate change based on specific populations are scarce. For the Lebanese community climate change is abstract enough that many ignore it. The media also has a role in this ignorance. With more highlight on the climate change impacts locally, and encouragement of public climate change awareness, people will be driven to be more inspired to take individual and community level actions. For citizens to acknowledge and accept the climate change and willingness to act in a pro-environmental behavior, the awareness should start at school by the teachers. The study is also helpful for identifying the relationship between scientific literacy and climate change awareness of prospective teachers. In this way, it adds to the existing literature and makes recommendations for future research.

Third; at the school level, understanding the scientific literacy and climate change awareness levels of prospective teachers quantitatively and qualitatively, is essential for government and educational sector as this might help in developing curricula that will enhance scientific and climate change literacy, and climate change awareness, as part of the science curriculum from kindergarten to secondary years.

Fourth; in terms of practice, it is hoped that, in the light of the findings of this study, the decision-makers in teacher education programs at universities, would emphasize on teaching content knowledge and pedagogical skills for prospective teachers to teach science and abstract concepts like climate change effectively. Moreover, to address curriculum designers in the Education Programs to emphasize the scientific literacy aspect in the curriculum and academic activities which will foster the level of awareness of prospective teacher with regards to climate change issue.

Fifth; participants of this study were exposed to scientific literacy questions based on real life experiences, which provided them the chance to think and reflect and perhaps indirectly contributed to their scientific literacy.

Chapter II

Literature Review

In Chapter 2, the literature pertaining to the scientific literacy and climate change awareness are reviewed. This chapter is divided into seven sections: (1) Scientific literacy, (2) prospective teachers' scientific literacy levels, (3) instruments to measure scientific literacy levels, (4) climate change awareness, (5) prospective teachers' climate change awareness levels, (6) instruments to measure climate change awareness, and (7) conclusion.

2.1 Scientific Literacy

The term "scientific literacy" seems to be elucidated in the 1950s, and most probably appeared in print for the first time in the publication of educational researcher Paul Hurd (Hurd, 1958) entitled *Science Literacy: Its Meaning for American Schools* (DeBoer, 1991; Roberts, 1983). In his publication, Hurd discusses the launching of Sputnik (the first satellite) into the earth's orbit by the Soviet Union in 1957, and how this sparked the Americans to question whether their children were receiving adequate scientific knowledge and skills to be able to participate in a society full of scientific and technological advancements. Hurd pointed out the need for science education which will meet the requirements of the future and hence the gap between scientific achievement and scientific literacy. In Hurd's words "We are raising a new generation of Americans that is scientifically and technologically illiterate" (Hurd, 1958). Although Hurd stressed the importance of scientific literacy he failed to provide a definition to it (Miller, 1983).

Since Paul Hurd used the term in 1958, many definitions for scientific literacy have been put forward. Reviews by science educators such as Laugksch (2000), DeBoer (2000), Dillon (2009), Holbrook and Rannikmae (2009), and Roberts (2007) disclosed the historical overview for understanding how the concept of scientific literacy evolved over the last 50 years. Laugksch (2000) discusses about various factors that can affect the definitions of scientific literacy. One of these factors is the several interest groups that are involved with scientific literacy. The researcher identified four interest groups; the first one being the science education community, including the science curriculum development groups and professional science education associations; which is interested with the nature, efficiency, and reform of the educational systems. The second interest group identified includes the social scientists and public opinion researchers; who are involved with science and technology policy issues. The third interest group comprised of sociologists of science and science educators using a sociological approach to scientific literacy. Finally, the fourth group detected is the informal and non-formal science education community and those engaged in science communication. Within this group lie those professionals who deliver educational and interpretive opportunities for the public to become acquainted with science. In addition, this group also includes those who write about science and report science as "news", personnel in science museums and science centers, botanical gardens and zoos, teams involved in science exhibitions and science displays, science journalists and writers, and relevant personnel in science radio and television programs. Hence, Laugksch (2000) pointed out with the different interest groups there appeared, different definitions of scientific literacy, the relative or absolute nature of the term, different purposes for promoting and different ways of measuring it.

Scientific literacy has also been defined by the National Academy of Sciences as the ability of a citizen not only to know basic knowledge of science and scientific facts, but also to understand and perceive scientific concepts, familiarity of how science and scientist work, the capability to be able to evaluate the outcomes of science, and the skill to engage in civic decisions (NAS, 2016). In line with NAS, the National Research Council (NRC, 2012) defined scientific literacy as one's ability to identify local and national scientific matters; understanding the world, and make an informed decision related to scientific and technological matters and assess information on the basis of the sources and methods used to spawn this information. OECD (2016) definition stated that scientific literacy is "the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen" (OECD, 2016, p.13). While the definition of scientific literacy continues to evolve, the basic parameters remain the same. These parameters include being familiar with scientific skills to make use of the scientific knowledge in real-life situations, ability to use scientific data and critically interpret and evaluate, explain phenomena scientifically and to make informed judgements in individual and social context (NRC, 2012; Hurd, 1998; Roberts & Bybee, 2014; OECD, 2016).

Roberts (2007) and Roberts and Bybee (2014) presented extensive review of the concept of scientific literacy as a means of framing outcomes for science education. Roberts (2007) created a heuristic framework and classified the approaches to scientific literacy along a continuum between two global overarching visions, Vision I and Vision II.

In Vision I, which reflects the primary aim of scientific literacy, Roberts (2007) posits scientific literacy as having a sound understanding of scientific findings and content. Nature of scientific knowledge and notion of how science works represent another dimension of Vision I. In the last decade, science education researchers and practitioners regarded the use of socioscientific issues contexts as means to transform science learning opportunities (Zeidler, 2015). However, for integrating socioscientific issues as part of classroom conversations, there was a need of a proof that serves as an evidence to connect the learning of science content to SSI-based instructional approach (Romine, Sadler, & Kinslow, 2017).

To that extent, several researchers have developed instructional units related to genetic technologies and genetic engineering and have shown that socioscientific issue-based instruction encourages learning of basic concepts (Sadler, Romine & Topçu, 2016; Venville & Dawson, 2010; Zohar & Nemet, 2002). Other researchers used the context of localized environmental socioscientific issues (Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007; Dori, Tal, & Tsaushu, 2003) and climate change (Klosterman & Sadler, 2010) to show the importance of SSI-based instruction approach and the result in substantial learning of students of ecological principles. Moreover, SSI-based instructional approach along with the incorporation of nature of science has shown to support the prospective teacher learning of nature of science concepts (Matkins & Bell, 2007; Bell, Matkins, & Gansneder, 2011). Similar findings were reported by Khishfe and Lederman (2006) and Eastwood et al. (2012) in high school context.

Vision II of scientific literacy, on the other hand, according to Roberts (2007), highlights the understanding and use of science beyond the conventional limits of science in a wider scale. For example, decision-making in real-life situations for issues underpinning science and affected by other disciplines such as ethics, economics and politics (Sadler and Zeidler, 2009). Vision II, in other words, focuses on the ways in which students conceptualize and use scientific knowledge and practices through explorations of complex issues. Hence, Vision II is critical for science education in solving problems related to socioscientific issues. While Vision

II is an important outcome but it is challenging to assess compared to conventional learning goals (Romine et al. 2017).

Promoting Vision II goals is crucial for science education and the SSI instructional approach has been proposed as an effective means of supporting learning (Zeidler, 2015). While many acknowledge the importance, yet the main challenge for science educators remains in the assessment of the effect of this method of instruction on student scientific literacy development (Sadler & Zeidler, 2009). Literature review shows different ways of measuring Vision II scientific literacy, including informal reasoning, argumentation, reflective judgement, and moral sensitivity (Romine et. al, 2017). To address complex SSI, an individual uses cognitive processes to make sense of and come up with a solution for the issue in hand. This is referred to as socioscientific reasoning (SSR). The SSR construct consists of four dimensions: (i) recognizing the intrinsic complexity of SSI; (ii) exploring issues from different perspectives; (iii) acknowledging that SSI are subordinate to ongoing inquiry; and (iv) investigating possibly biased information with skepticism (Sadler & Zeidler, 2009, p. 700).

With the growing interest by scientists and governments, who acknowledge the economic relevance of developing scientific skills, the use of the term scientific literacy is increasing in governmental and teaching bodies (McGregor & Kearton, 2010). However, with increase in demand of scientifically literate society, the need to prepare scientifically literate students deepens, to be better prepared and make informed decisions when faced with environmental, personal and social issues (Hicks et al. 2017). Hence, one of the central objectives of science education is preparing scientifically literate people, as access to information is easier and faster today than ever before. Some of this information pretense as science, which necessitates people to make decisions about the reliability of the resources they have access to, in order to be able to take the suitable decisions regarding their health, their environment and other socio-scientific relations. To have a strong stance and make a suitable decision, scientific literacy plays an important role (Saribas, 2015).

Some researchers position scientific literacy as of one's ability to address the science behind the problems and challenges faced in everyday life at the personal, political, social and economic levels (Bacanak and Gokdere, 2009; Karamustafaoglu et al., 2013). On the other hand, other researchers state that it is important to understand the nature of science, and the impact of science and technology on society to be scientifically literate person (Altun-Yalcin, et al., 2011; Chin, 2005; Cavas et al., 2013; Ozdemir, 2010). According to the different definitions of scientific literacy, individuals are placed on a continuum that ranges from less to more developed scientific literacy (Bybee, 1997; Koballa, Kemp & Evans, 1997). An individual with less developed scientific literacy level is capable of classifying knowledge as scientific and recall scientific information and an individual with high level of scientific literacy is able to understand the nature of science, the interdisciplinary understanding of science and the interrelationship of science, technology and society (Dani, 2009).

Internationally, one of the harmonized agreements was held on the goals of science education to empower students with the scientific knowledge in order to develop knowledgeable understanding of the world around them, develop science skills, attitudes, inquiry and to be able to make informed and balanced decisions regarding local or global socioscientific issues affecting many lives and become lifelong learners (American Association for the Advancement of Science, 2001; Australian Curriculum Assessment Reporting Authority (ACARA) 2014; CMEC

1997, NGSS 2013, NRC, 2011, 2013). To that purpose, policy documents from leading science education agencies targeted the core skills required to be essential for scientific literacy (e.g. AAAS, 1993; NRC, 2012; OECD 2016). According to *Science for All Americans* (SFAA) (American Association for the Advancement of Science [AAAS], 1993), one of the major publications from project 2061 along with "Benchmarks for Science Literacy", literacy has several attributes: 1) familiarity to the natural world; 2) the interdependency of science, technology and mathematics; 3) understanding the essential concepts of science, technology, mathematics and human enterprises; 4) Recognizing about their weaknesses and strengths; and 5) ability to use the acquired scientific knowledge and mindset for personal and societal use. Targeting undergraduate biology education, The *Vision and Change* report, argued that scientifically literate students "should be competent in communication and collaboration, as well as a certain level of quantitative competency and a basic ability to understand and interpret data" (AAAS, 2011).

Moreover, realizing the importance of scientific literacy for a scientifically literate future citizens and the need for "essential to full participation of citizens" (Bybee, 2008, p. 566), scientific literacy has been significantly emphasized in science curricula reforms. The spirit of the curricula reforms transcended various geographic boundaries. In the US, the Next Generation Science Standards (NGSS) were developed with the main objective of cultivating the new generation to be scientifically and technologically literate, for a scientifically educated society (NGSS, 2013). Moreover, the education system had to meet the need of the society and the labor market. With the shift of workload demands from unskilled jobs to skilled jobs which require education especially in science, technology, engineering and mathematics, and hence, the development of the NGSS had the objective of wellspring of economic growth and sustainability (NGSS, 2013). Another example is the Pan-Canadian Assessment Program *Common Framework of Science Learning Outcomes K to 12* proposed by the Council of Ministers of Education (CMEC, 1997).

Additional example comes from the *White Paper on Education and Training* published by the Commission of the European Communities (European Commission, 1995). The paper considers the European society is in a transitional phase with the dissemination of science and technology, and scattering of information technologies and relentless pressure on the world market (p. 7). The paper stipulates the need to prepare citizens who have adequate scientific awareness to make sure the proper functioning of democracy. According to the paper, democracy which is a system ruled by majority who have to take decision on major issues such as environmental and ethical issues, and because of the complexity of these issues and to be able to take informed decisions people have to possess not only background knowledge but also a certain scientific awareness. This need does not compel people to be scientific experts rather than being able to make educated decisions which will affect their environment and be able to make knowledgeable decisions (p. 10).

Another example comes from the Australian Curriculum Assessment and Reporting Authority (ACARA). The Australian science curriculum was reformed with the rationale which states “curriculum supports students to develop the scientific knowledge, understandings and skills to make informed decisions about local, national and global issues” (ACARA, 2014, p.1). The structure of the Australian science curriculum encompasses three interrelated strands of science: *Science Understanding*, *Science Inquiry Skills* and *Science as Human Endeavor*.

This later will help students appreciate the nature of science and knowledge of science and how these will influence peoples' lives (ACARA, 2014).

The final example is derived from the Lebanese context, BouJaoude (2002) with an attempt to investigate whether or not the Lebanese science curriculum has the potential of fostering scientifically literacy, conducted a study to investigate the balance of scientific literacy themes in the new Lebanese curriculum. BouJaoude developed a framework, for the purpose of the study, and analyzed and categorized the general objectives, introductions, instructional objectives, and activities of Grades 1, 2, 4, 5, 7, 8, 10 and 11. The researcher found that the Lebanese curriculum emphasizes the knowledge of science, the investigative nature of science, and the interaction of science, technology and society but neglects "science as a way of knowing" although it appears in the general objectives of the science curriculum.

Scientifically literate students could be described in a number of ways in Shen's (1975) terms; practical, civic and cultural. A student is said to be literate in a practical way when they are able to solve problems for survival; in a civic way, to participate in debate and decision making; and to comprehend science as a human endeavor. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically (OECD, 2016, p. 13).

This section provided an insight of the early use of the word scientific literacy and its different definitions. As Laugksch (2000) mentioned, the diverse definitions depend on various factors, one of them is the different interest groups. The section further deliberates on Roberts' framework of scientific literacy over a continuum between two overarching visions Vision I and Vision II. While Vision I focused on sound understanding of scientific findings, science content, nature of scientific knowledge, and how science works, Vision II highlights the use of science beyond its conventional limits for example in real-life situations and solving problems in socio-scientific issues.

The goal is to prepare scientific literacy students who, in the future, can make informed and balanced decisions regarding challenges faced in everyday life at the personal, political, social, and economic levels. To that purpose, different reform movements were discussed in the section.

2.2 Scientific Literacy and Prospective Teachers

This section reviews previous studies that have focused on determining the scientific literacy levels of teachers. While the main goal is determining the scientific literacy levels, the studies differ in the year, the emphasis and the courses taken by the prospective teachers. Some researchers have examined a possible relationship between the levels of scientific literacy and a factor such as gender, scientific attitude, environmental literacy, lifelong learning tendency.

Chin (2005) investigated the scientific literacy of first-year freshmen Taiwanese prospective teachers majoring either in elementary education or science education in four colleges of Taiwan. In the study, science education prospective teachers were chosen as they had completed advanced science courses. The prospective teachers from the social studies elementary track were selected to compare their levels of scientific literacy and attitude towards science to that of coming from science education majors. For his study, the researcher chose two instruments: The Chinese version of TBSL for scientific literacy level assessment and TOSRA for assessing prospective teachers' attitudes toward science. Statistical results of this study indicated that the prospective teachers coming from a science major scored higher in scientific literacy compared to those coming from elementary education majors. Taiwanese prospective teachers in the science education majors scored considerably higher than the elementary education in the TBSL and all its scales. Moreover, elementary education prospective teachers also responded more frequently as “don’t know” particularly in the domains of nature of science and physical science. The author confirmed that the level of scientific literacy of Taiwanese first-year prospective teachers is at a satisfactory level.

A number of authors (Altun-Yalcin et al., 2011; Bacanak & Gokdere, 2009; Çavaş et al., 2013; Karamustafaoğlu et al., 2013; Ozdemir, 2010; Yetisir, 2007) examined the scientific literacy levels within the Turkish context. Bacanak and Gökdere (2009) investigated the level of scientific literacy and the extent of relationship between the levels of scientific literacy and gender. The participants were from a primary school teacher training program in the Faculty of Education at Amasya University. The sample of the study was comprised of ninety female and forty-two male, fourth year students from elementary education program. The researchers developed a 35-item multiple choice test, with a correlation coefficient of 0.80. Statistical findings of the study showed that participants received highest average on the nature of science and scientists’ properties items, and lowest on the science and technology items. Moreover, although the mean scores of females were higher than those of male participants, the difference was not statistically significant.

Altun-Yalcin et al. (2011) examined the scientific literacy levels of prospective teachers at different grade levels in the Science Teacher Training Department, at Bayburt University, in Turkey. According to the author scientific literacy is the knowing of scientific facts and concepts and understanding how science works. The study also aimed to explore the effectiveness of the education faculties in Turkey in preparing scientifically literate future teachers, who are responsible for the education of the society. To assess the level of scientific literacy of prospective teachers, the data was collected based on a Likert-type scale developed by Derman, Dogu and Godek Altuk (1989). The authors found that the education faculties affect the prospective teachers' scientific literacy based on grade level without any statistically meaningful difference between male and female students.

In a similar vein, Cavas et al. (2013) investigated whether the prospective elementary science teachers, from the freshman and senior levels, at 10 public universities in Turkey, have a satisfactory level of scientific literacy in relation to different factors such as attitude toward science, gender, year in university and educational level of parents. The researchers chose the definition of Dawson and Venville (2009) for scientific literacy. The authors translated to Turkish, validated and used the Test of Basic Scientific Literacy (TBSL) instrument developed by Laugksch and Spargo (1996a, 1996b) to investigate the scientific literacy levels of university students. Moreover, the authors used the Scientific Attitude Inventory (SAI - II) to measure the participants' attitude towards science. According to findings of the study; elementary prospective teachers do not have a satisfactory science and technology literacy levels. However, the elementary prospective teachers have sufficient levels of scientific literacy especially the 4th year students in all sub-dimensions of scientific literacy. Interestingly, the authors claim the level of mother's education had a significant effect in determining the scientific literacy of students. While the fathers' education didn't make any difference. Unlike previous studies which showed a positive correlation between scientific literacy and attitude toward science (Bybee & McCrae, 2011), the correlation in this study was very weak.

With the increase of environmental problems, the importance of teaching about environmental issues becomes crucial to raise students' curiosity and enthusiasm, to learn about environmental issues, which in turn will influence their overall scientific literacy (Saribas, 2015). Since teachers are entrusted to prepare the future citizens, Saribas (2015) conducted a study to determine Turkish prospective teachers' understanding of scientific literacy with respect to the environment and analyzed the correlation. To conduct his experiment, Saribas used TBSL, SEL (The Scale of Environmental Literacy), Lifelong learning Tendency Scale (LLTS). The author found relatively low but significant relationship between scientific literacy and all the dimensions of environmental literacy. Moreover, participants who had the highest level of lifelong learning tendency did not have high score of scientific literacy.

Still within the Turkish context, the literature showed that prospective teachers, during their first and fourth years at university, demonstrated a borderline to low scientific literacy levels and the researchers highlighted a need of improvement (Cavas et al., 2013; Karamustafaoglu et al. 2013). In the light of the reported studies, other researchers examined prospective teachers during their four-year teacher preparation program and reported that the highest level of scientific literacy demonstrated by prospective teachers was during their final year of study (Altun-Yalcin et al., 2011; Ozdemir, 2010).

Al Sultan et al. (2018) sought to determine the scientific literacy of elementary prospective teachers in the Teacher Education Program (TEP) at a mid-sized university in the Midwestern United States. Additionally, the researchers intended to find out if there was a relationship between scientific literacy and self-efficacy among the science teacher candidates. The researchers relied on NRC's (1996) definition of scientific literacy, which unlike other definitions, included the ability of an individual to converse and evaluate scientific and technological material. Two groups were involved in the study, prospective teachers enrolled in introductory science methods course and those enrolled in advanced science methods courses. Furthermore, the researchers collected data from the participants by administering three instruments: Test of Basic Scientific Literacy (TBSL), Science Teaching Efficacy Belief Instrument (STEBI-B), and Beliefs about Teaching (BAT). The researchers found that participants enrolled in advanced science methods course have a higher scientific literacy level compared to those participants in the introductory course. The study also showed a positive relationship between scientific literacy and self-efficacy among advanced prospective science course participants.

In the Lebanese context, Dani (2009) examined the aspects of scientific literacy along with the teachers' purpose for teaching science. The author employed a qualitative study to examine eight intermediate and secondary grade teachers' purposes for teaching science and aspects of scientific literacy, using BouJaoude's (2002) framework of scientific literacy. The author concluded that teachers' main purpose of teaching science was to equip students with "knowledge of science", "the interaction of science technology, and society", "the investigative nature of science"; the three aspects of scientific literacy as per BouJaoude's (2002) framework. The 8 participants believed that the breadth and depth of scientific knowledge will prepare students to discover the world around them. Furthermore, all participants recognized the national textbooks and official exams as contextual factors which focus on two aspects of scientific literacy "knowledge of science" and "investigative nature of science". Lebanon's pluralistic society is another factor identified by teachers which will impede the implementation of "interaction between science, technology, and society" goals, as teachers had to encourage respect of diversity of prospects with regard to social, ethical and moral issues in science.

This section presented the literature review regarding the scientific literacy of prospective teachers. While the researchers relied on quantitative studies and different definitions of scientific literacy, yet most of them relied on TBSL to collect data regarding the scientific literacy level (Al. Sultan et al. 2018; Cavas et al., 2013; Chin, 2005; Saribas, 2015). In the Taiwanese context, prospective teachers coming from science majors scored higher in scientifically literacy compared to that of coming from the elementary education majors (Chin 2005) while in the Turkish context elementary prospective teachers do not have a satisfactory scientific literacy levels during their first year of studies however show an improved level of scientific literacy during their fourth year of studies (Altun-Yalcin et al., 2011; Cavas et al., 2013; Karamustafaoglu et al., 2013). In the Lebanese context, the scientific literacy levels of in-service teachers were determined in a qualitative study (Dani, 2009), using BouJaoude's (2002) framework of scientific literacy however the study is constrained to the views of 8 participants which leaves room for more profound investigation with regards to Lebanese prospective teachers.

2.3 Instruments for Measuring Scientific Literacy Levels

The literature review shows few instruments, to the researcher's knowledge, used to measure scientific literacy levels. These instruments were chosen to be discussed in this section as the psychometric properties of these instruments are well known.

Romine et al. (2017) developed an instrument, *Quantitative Assessment of Socio-Scientific Reasoning* (QuASSR), which aims at measuring the socioscientific reasoning. This instrument stems from Roberts Vision II framework of scientific literacy, which highlights the idea that students have to apply scientific content knowledge through investigating complex social issues. However, since little decision-making and problem-solving skills can be carried out in the absence of factual and conceptual knowledge (Saribas, 2015), this study is interested to measure scientific literacy of prospective teachers which lies in Roberts Vision I framework of scientific literacy. Hence, this instrument cannot be used to answer the research questions of this study.

One of the reasons for the need to construct a paper-and-pencil test to measure scientific literacy, as stated by Laugksch and Spargo (1996a, 1996b), emerged from the wide range of definitions and explanations of the term. The definitions mainly relied on the goal for which it was promoted. Arguments in support of scientific literacy, allowed varied interpretation of this notion and led to a concept which is "diffuse" and "ill-defined", and difficult to assess. It was only after Miller's (1983) publication proposing the multi-dimensional model of scientific literacy, that significant progress was noticeable in measuring scientific literacy in a widely applicable and large-scale surveys (Laugksch & Spargo, 1996). In his paper Miller (1983) postulated that scientific literacy has three dimensions: an understanding of the norms and methods of science (i.e., the nature of science); an understanding of key scientific terms and concepts; and awareness and understanding of the impact of science and technology on society.

Test of Basic Scientific Literacy (TBSL) instrument was developed by Laugksch and Spargo (1996a, 1996b) to measure the scientific literacy of high school graduates. The instrument was prepared based on the scientific literacy objectives in the report *Science for All Americans* (AAAS, 1990) and Miller's (1983) scientific literacy categories. Laugksch and Spargo (1996b), developed TBSL argue that in Miller's Framework, with the exception of the impact of science and technology on society dimension, the other dimensions of scientific literacy were grounded on small number of items and unspecified content validity. Moreover, the authors mention the use of Miller's methodology requires face-to-face or phone interviews which are both time-consuming and expensive. This is less appealing to less well-funded research projects or research projects with a small number of personnel. TBSL thus comprises of scientific literacy test-items that cover wide range of different content areas, understanding of ideas and attitudes towards science. It consists of three subtests, constituting to Miller's three-constitutive dimensions of scientific literacy, the Nature of Science Subtest (NSST), the Science Content Knowledge Subtest (SCKST), and the Impact of Science and Technology on Society Subtest (ISTSST). Hence, the TBSL is an improvement of previous attempts to measure scientific literacy in a composite manner along the "three-constitutive dimension of Miller's framework (Laugksch and Spargo, 1996b).

TBSL instrument comprises of 110 items, of factual information, comprehension of concepts, and attitudes toward science. The arrangement of the number of test items is comparatively even, with the life science (24) and the nature of science (22) being the most, and the physical and chemical sciences (14) containing the fewest test items. The dimensions of scientific literacy in the TBSL are nature of science (22 items), science content knowledge (72 items), and the impact of science and technology on society (16 items) (Laugksch & Spargo, 1996b). Science content constitutes (1) earth science, (2) life science, (3) physical science (4) health science. Responses of "True", "False" or "don't know" are required. This type of format is appropriate for an instrument comprised of large number of items. The addendum of "don't know" option minimizes the probability of guessing (Saribas, 2015). According to Laugksch and Spargo (1996) to be considered “scientifically literate” the participant must have at least 68 right answers out of 110 test items.

The TBSL being valid and reliable, could be used for large-scale studies with relatively little expenditure of time and money (Laugksch & Spargo, 1996b). Various authors have used TBSL in their studies (Al. Sultan et al. 2018; Cavas et al., 2013; Chin, 2005; Saribas, 2015). Saribas (2015) pointed out that TBSL is an old instrument, based on old curriculum that excludes items which tests decision-making and problem-solving skills (Saribas 2015).

Another instrument which has been developed to evaluate scientific literacy is *Test of Scientific Literacy Skills* (TOSLS) (Gormally, Brickman, & Lutz, 2012). According to Gormally et al. (2012) the definition of scientific literacy which makes up the framework of TOSLS is based on Project 2061 and PISA definition of the concept of scientific literacy “the capacity to use scientific knowledge to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity” (OECD, 2003). The robustness of TOSLS lies in the fact that the test is that it is constructed, validated and assessed, in another words, the psychometric properties of the instrument is known (Gormally et al., 2012). The instrument comprises of 28 multiple-choice questions that are within the framework of real-world problems (Gormally et al., 2012). The researchers identified two broad categories of scientific literacy skills: (1) Skills related to the use of inquiry which leads to scientific knowledge, (2) Skills related to data organization, analysis and interpretation.

While both TBSL and TOSLS are psychometrically sound tests for measuring scientific literacy levels yet TOSLS will be used in this study. The reason behind this choice is fivefold.

First, TOSLS gauges the proficiency in scientific literacy skills to critically evaluate and solve SSI in and beyond the science course (Gormally et al., 2012), which is one of the main goals of science education (AAAS, 1990, 2010; Bybee, 1993; DeBoer, 2000). With the low scientific literacy scores of Lebanese 15-year-olds in PISA assessment one way to tackle this issue, is to investigate the scientific literacy levels of prospective teachers, as these are the future teachers who are entrusted with the responsibility to prepare scientifically literate students at early stages of formal education.

Second, since science and scientific skills required are constantly evolving, with various curricular reforms, discussed in the literature review section, it is important to measure scientific literacy levels based on a relatively recent definition of scientific literacy. While TBSL is based on AAAS (1989) scientific literacy definition and goals, TOSLS is based on scientific literacy in line with a relatively recent document for the goals of science education; OECD (2003).

Third, TOSLS instrument items do not depend on a specific discipline, rather it is based on real world problems hence it could be administered to the participants regardless of their background.

Fourth, the test is divided into two distinct parts as “understanding methods of inquiry that lead to science knowledge” and “organize, analyze and interpret quantitative data and scientific information (Gormally et al., 2002). While TBSL is a refinement of Miller’s framework of scientific literacy (1989).

Finally, TOSLS test is short, 28-multiple choice question type instrument and could be easily administered and analyzed.

2.4 Climate Change Awareness

The climate change discourse is surrounded by numerous controversies. However, according to Keeling (1960) warnings on the possibility of human impacts, or anthropogenic factors, on climate change, emerged in late 19th century when Charles D. Keeling from *Scripps Institution of Oceanography* started measuring the atmospheric CO_2 concentration in ice-cores. The preliminary findings of Keeling's study revealed the increase in concentration of the atmospheric CO_2 with clear seasonal variations, and this increase was a link to industrial expansion (Keeling, 1960).

Although with a long-standing history, lately climate change has become one of the substantial issues faced by communities worldwide (Nordhaus, 2019). Various effects have been observed in different parts of the world based on geographical and other factors, and immediate measures should be adopted to mitigate the impacts of climate change on ecosystem, coastal systems, food and water security, fire regimes, and society (Australian Academy of Science, 2015; Bureau of Meteorology and CSIRO, 2018; Zhai et al., 2018).

Climate change according to Ezeudu (2009) refers to the long-term substantial change in the average weather that a particular region experience. Nzewi (2009) stressed that climate change is the average temperature of earth's atmosphere, oceans and landmasses. Nwagu and Nzewi (2009) defined that climate change is a critical change in weather including the wind, precipitation and temperature over a long duration. According to *The Science of Climate Change* Report (Australian Academy of Science, 2015) the term "climate", in its more comprehensive sense, refers to "a statistical description of weather and of the related conditions of oceans, land surfaces and ice sheets. This includes consideration of averages, variability and extremes" (p. 5).

Scientists assert that the earth's climate is altering and will continue to change throughout this century and beyond, but the real cause and the aftermath of these changes, and mitigation measurements are not fully understood (Zhai et al., 2018). With the increase of greenhouse gas emission and increase in the concentration of these gases in the atmosphere, due to human activities, it is expected that, the global average air temperature will warm by around 4 °C above the mid-19th century temperatures (Australian Academy of Science, 2015).

Being a complicated issue, climate change is a difficult concept to understand and the difficulty emerges from the fact that the changes in the climate require long periods of time and sometimes are too minor to be measured quantitatively (Van der Sluijs, 2012). Unlike a typical science which has a specific discipline, climate change science bestrides many science disciplines such as Physics, Chemistry, Biology, Mathematics and Geography in addition to their sub-disciplines including atmospheric physics and chemistry. This makes climate change an interdisciplinary science (Bhaskar, 2010) and requires an interdisciplinary teaching methodology (Pruneau, Gravel, Bourque, & Langis, 2003). Moreover, the two terms "climate change" and "global warming" are interchangeably used and confused (Schuldt, Konrath & Schwarz, 2011). To this extent, some assume that mass media and teachers have a significant role in this confusion. Many scholarly research articles studying climate change focus on mass media coverage (Segev & Baram-Tsabari, 2010). In addition, there are studies showing the effect of teachers on public understanding of climate change, but fewer studies on the effect of media on public understanding of this concept (Savasci-acikalin & Acikalin, 2011). Teachers and students, just like the rest of the public, are affected by the questionable and perplexing messages that the mass media, internet, and scientists produce about climate change. However, it is the responsibility of the science teachers not only to be informed but also be certain about the science of climate change to counterbalance the harm of mass media and provide their students with a solid and rigorous idea of the issue (Bissel, 2011).

In addition to the challenges mentioned in the previous paragraph, teachers also face additional challenges regarding public's perceptions of climate change (Bissel, 2011). Hulme (2010) refers to the climate change as a "postnormal" science, where the cost of poor decision-making can be tremendous, with the lack of needed scientific information to make these decisions. The complex and in Hulme's words "postnormal" nature of climate change issue, often leaves members of the public including students feeling unqualified and hence discouraged to enter any debate related to the issue. People often feel they don't understand the climate change issue or that it is quite complicated for them and hence are indifferent (Bissel, 2011). Moser and Dilling (2004) identified another challenge in regards to the public perception of climate change issue and in their words, they referred to as a "creeping" problem (p 34). Taking into consideration the effects of climate change slowly accumulate over time, and it takes time to show tangible effects, there seems to be no hesitation to address this problem as people have more urgent matters to deal with and less time to care about the climate change (Bissel, 2011).

In his article, Bissel (2011) identifies some hurdles, for science educators to become more knowledgeable on the issue of climate change, such as time limitation, access to primary science resources as well as opportunities to have a first-hand interaction with scientists. As a consequence, the author adds, teachers rely heavily on the internet and mass media, despite of the limitations of these resources. Science teachers are habituated in teaching sciences; biology, chemistry and physics, in a compartmentalized way, especially at the secondary level addressing each subject as a separate instead of interdisciplinary approach. Chambers (2009) reproaches this to the segregation of high school classes into diverse subject areas as well as a complex issue such as climate change is not served well by the teacher education programs, hence the need of the support of the teacher education programs and the curriculum developers to help teachers understand the interrelationships of the different science topics and the links among them. Other researchers also highlight the need for science educators to understand the potential of natural versus human-induced factors affecting climate change, ways to mitigate and adapt to climate change issue (Daskolia, Flogaitis, & Papageorgious, 2006; Papadimitriou, 2004). Lack of conceptual understanding and influence of perceptions about climate change has shown to affect self-efficacy to teach it (Bleicher & Lindgren, 2005). With similar findings, Celikler and Aksan (2011), Fortner (2001) and Dove (1996), demonstrated that teachers do not have the sufficient knowledge and awareness of environmental issues to spread it to students. In this vein, US National Oceanic and Atmospheric Administration and the American Association for the Advancement of Science developed a focused guide to support science teachers to align their lessons to science content standards and promote greater understanding of the science behind the climate change issue (U.S. Global Change Research Program, 2009).

Teachers can teach students critical thinking skills and media awareness to be able to evaluate resources on the internet and mass media in order to be able to recognize the credibility of the resources in the context of climate change (Bissel,

2011) and hence become “critical consumers of information” (Heffron & Kharra Valmod, 2011). These skills will also provide students with the right tools in contexts beyond the climate change issue (Bissel, 2011). However, in addition to the complexities of this global environmental issue, teachers and students also face the challenge of strong emotions while discussing the potential relationship between the anthropogenic reasons of climate change and global warming (Broughton, Pekrun, & Sinatra, 2012). A study reported emotions like anger, hopelessness, fear, and anxiety which can impact the teaching (Moser, 2007).

Realization of scientific literacy necessitates educating students about the social issues including their underpinning scientific and technological principles. This also ensures the success of the science education reforms. In the late seventies and early eighties with the blooming of the Science-Technology-Society (STS) movement, in an attempt to resolve the societal concerns of the time required “a different kind of science curriculum” as Hofstein and Yager argued (1982, p. 540). Addressing societal concerns like different types of pollution, overpopulation, water shortage, deterioration of resources, dangers of nuclear proliferation are the debates of all times.

A study was conducted by Ezeudu et al. (2017) to determine the climate change awareness and attitude of senior secondary school students in Abia State, Nigeria. Data was collected using the *Awareness Scale for Climate Change* (ASCC) and *Climate Change Attitude Scale* (CCAS). The study found that the 640 participants out of 2012 possessed low levels of climate change awareness as well as low attitude towards climate change. This study was duplicated using the same measuring instruments by Lopez and Malay (2019), in the context of the Philippines, and found out that the senior high school students showed moderate to high level of awareness of climate change. Carr et al. (2015) stated that students' knowledge of climate change is replete with inaccuracies, misconceptions, and in some cases lack of knowledge which hinder the development of awareness and positive attitude towards climate change. Furthermore, Dal et. al (2015) stated that there was no statistically significant difference among the social studies and science teachers' awareness on climate change, which necessitates to raise the awareness of teachers in regards to the environmental problems and design of courses about climate change awareness at university levels and focus on the instructional skills for teaching of environmental problems such as climate change.

Environmental education and awareness can help overcome future environmental problems. According to the United Nations Educational Scientific and Cultural Organization (UNESCO, 2019), education is fundamental element in helping people to understand climate change, address the impact of global warming, promotes informed decision-making, and helps in increasing the adaptation and mitigation capabilities of communities. As the teachers are the bridge between education and the students, there is a positive correlation between the teachers' climate change awareness and their students (Dal et al., 2015).

Having clarified the importance of preparing scientifically literate citizens, who can take decision regarding any science-based social issues, such as climate change, at the personal or at the societal levels, it is crucial to examine the literature about the climate change awareness of prospective teachers who are accountable to prepare scientifically literate future citizens. Hence, the second aim of this study intends to examine the climate change awareness of prospective teachers, as the future frontline actors between education and the students.

2.5 Climate Change Awareness and Prospective Teachers

There exists a considerable amount of literature on how climate change awareness initiatives at the community level might give rise to positive outcomes. For example, Barnett and Campbell (2010) report that the levels of knowledge and awareness can affect people's attitudes and perceptions about climate change and their future approach to local environmental changes. Previous studies have shown the effect of teachers' beliefs to their teaching content and pedagogy (Glackin, 2016; Mansour 2010, 2013). Stevenson, Peterson, and Bradshaw (2016) have also suggested the influence of teachers' confidence in teaching climate change to an increase in students' confidence in their knowledge and learning process. Besides, literature also revealed that students have misconceptions and confusion about climate change (Choi, Niyogi, Shepardson, & Charusombat, 2010; Kilinc, Stanisstreet, & Boyes, 2008; Liarakau, Athanasiadis, & Gavrilakis, 2011; Pruneau, Moncton, Liboiron, & Vrain, 2001; Sheperdson, Niyogi, Choi, & Charusombat, 2009; Sheperdson, Niyogi, Roychoudhury, & Hirsch, 2012). The literature also revealed the alternative conceptions of elementary school students regarding climate change (Choi et al., 2010; Lambert, Lindgren, & Bleicher, 2012; Pruneau et al., 2001). Some studies stated that students' alternative conceptions are derived from their teachers (Trumper & Gorsky, 1996; Tsaparlis, 2003). Research studies on prospective teachers' ideas about climate change also showed the misconceptions and misunderstandings of prospective teachers about concepts underlying climate change (Daskolia, Flogaitis, and Papageorgiou, 2006; Dimitriou, 2003; Groves & Pugh, 2002; Khalid, 2001, 2003; Lambert, Lindgren, and Bleicher, 2012; Papadimitriou, 2004; Summers, Kruger, Childs, & Mant, 2000). For example, Lambert et al. (2012), assessed the 126 in-service and prospective elementary teachers' knowledge about the climate change pre- and post- instructional intervention. The findings showed participants had the same naïve and alternative conceptions as those of middle- and high- school students even after instruction. Papadimitriou (2004) investigated the understanding of climate change, green-house effect and ozone layer of 172 Greek elementary prospective teachers. The findings also supported by earlier research, showed that prospective teachers hold: confusion between weather with climate, inaccurately relating the climate change to ozone depletion, incorrectly relating climate change to ozone layer depletion. Daskolia et al. (2006) studied 159 in-service kindergarten teachers' conceptual framework on the ozone layer depletion, using a free word association methodology. Again, the study revealed misconceptions and misunderstandings and confusions between ozone hole and greenhouse effect and excessive emphasis on the potential hazards of ozone layer on human health. Summers et al. (2000) conducted in-depth interviews with 12 elementary in-service teachers to investigate their understandings related to specific environmental issues: biodiversity, the carbon cycle, ozone and global warming. The findings support other studies about teachers' misconceptions and alternative conceptions such as "holes" result in global warming and car exhausts release chemical which cause ozone depletion.

In the Turkish context, Dal et al. (2015) conducted a study to investigate the climate change awareness of prospective science teachers and their willingness to act for pro-climate change friendly behavior. To that purpose the authors relied on convenient sampling method and 603 prospective teachers enrolled in 3 different Turkish undergraduate teaching programs were selected. The participants were in their second, third or fourth year at university. The authors employed quantitative methodology which prescribes the use of the *Awareness to Climate Change*

Questionnaire (ACCQ) originally developed by Halady and Rao (2010), which aims to determine any statistical significance between awareness and behavioral change. The authors found that the prospective science teachers had high level of awareness on all three subscales of ACCQ in addition to the subscale of propensity of willingness to act. The authors associated this positive correlation between climate change knowledge, understanding issues related to climate change and climate change awareness to the Turkish teacher education program curriculum which includes content on environmental education and global issues. In contrast, a study conducted by Kollmus and Agyeman (2002) showed that there is no direct relationship between climate change knowledge, climate change awareness and act for pro-climate change friendly behavior. The authors highlighted internal and external factors which influence pro-environmental behaviors. The two important internal factors being the climate change knowledge and climate change awareness in addition to external factors like social, cultural and economic.

Hidge, Oztekin and Sahin (2017) studied the awareness, beliefs, values and behaviors of Turkish prospective science teachers related to climate change. Prospective teachers were chosen as participants as they are responsible to empower students with climate change education, knowledge, values, attitudes and behavior as these attributes are important for pro-environmental behaviors of the future citizens. The authors showed that the participants' information regarding climate change was mainly through television, internet and newspaper and expressed positive views to mitigate it. Moreover, the respondents had an uncertain stance about climate change when they had to link the Turkish flood to climate change. The study highlighted that prospective teachers who value nature showed a positive behavior for mitigating climate change. This is significant, as teachers who showed high pro-environmental values showed less skepticism and were more serious of climate change.

This section provided a framework regarding previous studies conducted about climate change awareness of prospective teachers. It indicated that despite decades of research, studies in determining the climate change awareness of prospective teachers is limited globally. Although, literature also showed that teachers hold misconceptions, misunderstandings and alternative conceptions, however, investigating these aspects are beyond the scope of this study. Within the Lebanese context climate change awareness is still insufficiently explored. To fill this literature gap, this study intends to explore the scientific literacy and climate change awareness of prospective teachers and whether they are related.

2.6 Instruments for Measuring Climate Change Awareness Levels

A number of instruments or structured questionnaire have been used to measure climate change awareness of which the most known are Oruonye's (2011) structured question methodology, Rahman, Tasmin, Uddin, Islam and Sujauddin's (2014) *Climate Change Awareness Index* (CAI), Njoku's (2016) *Climate Change and Sustainable Development Awareness Level (CCSDA)*, Carr's (2015) Likert-scale based survey, Ezeudu F., Ezeudu S., and Sampson's (2017) Likert-scale based survey, and Bello's (2014) *Secondary School Students' Perception of Climate Change Questionnaire* (S^3PC^2Q). These tests employed structured questions (Oruonye's, 2011; Rahman et al., 2014), binary yes-or-no answer type questions (Njoku, 2016), yes-or-no type and open-ended questions (Bello, 2014) and Likert-scale based questionnaire (Carr's, 2015; Lopez & Malay (2019).

Oruonye (2011) designed a structured questionnaire and interviewed 225 university students to collect data about the students' awareness of climate change, its causes, effects and mitigation measures.

Rahman et al. (2014) studied the role of diverse demographic variables and scholastic background of Bangladesh students on climate change awareness. For that purpose, the authors prepared structured questionnaire consisting of several sections. Besides the demographic information of the participants, educational background of the parents was also part of the survey. The authors constructed *Climate Change Awareness Index* (CAI) as an indicator of the climate change awareness of students.

Njoku (2016) studied the awareness of climate change and sustainable development issues among Junior secondary school students in Nigeria. The author targeted secondary students based on the presumption that education will affect the population. To that purpose the researchers developed a questionnaire *Climate Change and Sustainable Development Awareness Level (CCSDA)* made up of Section A for demographic data collection, Section B for awareness level of climate change, and Section C for collecting data on sustainable development awareness level. The researcher validated the questionnaire using face and content validity. The reliability coefficient was calculated to be 0.78 using the Pearson Product Moment Correlation (PPMC).

Carr (2015) studied the climate change awareness of secondary school students. The researcher developed sixty "tick box" survey questions, including the use of Likert scales which was piloted among students. The survey consisted of four sections: Participant profile (Q1-4), personal views and attitudes towards climate change (Q5-20), climate change knowledge (Q21-56) and sources of climate change information (Q57-60).

Lopez and Malay (2019) studied the climate change awareness and attitudes of senior high school students, in Philippines. The authors modified and used previously published climate change awareness survey of Ezeudu et al. (2016) and Carr (2015). The final version of the survey consisted of 25 statements and four parts. Part I, information about the participants demographics; part II, information about awareness regarding climate change (15 statements); part III, attitude towards climate change (10 statements), and part IV, sources of climate change information. Four-point Likert scale was used to record the responses.

Bello (2014) investigated the climate change awareness of secondary school students and their perceptions about the causes of climate change. To that purpose the researcher constructed an instrument called *Secondary School Students' Perception of Climate Change Questionnaire* (S^3PC^2Q). The questionnaire is made up of three sections. Section "A" to collect the demographic variables of the participants; section B, which intends for information on the causes of climate change is a twenty-item question on "Yes" and "No" response and section C which is to collect data on the sources of information on climate change and willingness to be agent of information dissemination is an eight-item open ended questions. The reliability of the questionnaire was determined by test re-test measure of reliability and the data collected was subjected to Pearson's Product Moment Correlation and a reliability coefficient of 0.76 was obtained.

For the purpose of this research the 15-item statements of Ezeudu et al.'s (2016) open access instrument was used. The reason behind this choice is fivefold.

First, this study aimed to include both four-point Likert scaled statements and qualitative data obtained through semi-structured interview's hence the use of only structured questionnaires (Oruoyne, 2011; Rahman et al., 2014) was avoided.

Second, as noticed in the previous paragraphs, Lopez and Malay (2019) modified and used previously published Ezeudu et al.'s (2016) 15 four-point Likert scale climate change awareness statements. Besides Lopez and Malay (2019) included statements related to attitude, sources of initial and additional information of climate change which are beyond the scope of this study.

Third, Carr's (2015) three-point Likert scale-based instrument included 15 statements related to the views and attitudes of climate change, 35 statements related to climate change knowledge and 3 statements related to climate change information all of which do not fall within the purpose of this research.

Fourth, not only Njoku's (2016) instrument was based on 10 statements of awareness of sustainable development and 15 statements of climate change awareness, but also the instrument uses only binary yes-or-no answers. In their article Wu and Leung (2017) recommended increasing the number of Likert-points to decrease the cons of Likert-scale based questionnaire results, and bring it closer to continuous scales. Similarly, use of Bello's (2014) instrument was avoided as it was also based on binary yes-or-no answers. In this regard, Ezeudu et al.'s (2016) scale is based on four-point Likert scale-based questionnaire hence provides better results than the aforementioned instrument.

2.7 Conclusion

The word scientific literacy evolved over time with the early use of the word in the 1950s. This evolution came as a result of change in goals of science education, which not only led to science curricular reform movements, but also change in the nature of the concept of scientific literacy, and the importance of preparing a scientifically literate students; the future citizen.

While the scientific literacy level of a citizen depends on the person's particular context, yet literature showed the importance of prospective teachers' as frontline actors of empowering students; the future citizens, with scientific literacy.

A closer look at the literature on levels of scientific literacy levels of prospective teachers, showed a number of gaps and shortcomings. First, the scientific literacy levels have previously been assessed only to a limited extent, and studies in the Lebanese context, at least to the researchers' knowledge, are missing. Second, previous studies have exclusively relied on quantitative analysis to measure the scientific literacy level of prospective teachers (Altun-Yalcin et al., 2011; Bacanak & Gokdere, 2009; Cavas et al., 2013; Chin, 2005; Karamustafaoglu et al., 2013; Ozdemir, 2010).

Literature review pertaining climate change strongly suggested that students have misconceptions and alternate conceptions related to concepts related to climate change, some of which are due to teachers. Although climate change knowledge of prospective teachers is beyond the scope of this study yet it is importance to measure the levels of climate change awareness of the prospective teachers as several studies have reported the effect of teachers' knowledge, attitude affects their teaching and pedagogy which will affect the pro-environmental behavior of their students. With limited studies in investigating the levels of climate change awareness of prospective teachers in general, and in the Lebanese context in particular, this study comes to fill this gap.

To the researchers' knowledge no prior study aimed at investigating a possible relationship between the prospective teachers' levels of scientific literacy and climate change awareness.

In short, a closer look to the literature on the scientific literacy and climate change awareness of prospective teachers in Lebanon, however, revealed a number of gaps, hence my research questions:

a. What are the scientific literacy levels of prospective teachers in private universities in Lebanon?
b. What are the climate change awareness levels of prospective teachers in private universities in Lebanon?
c. What relation exists, if any, between Lebanese prospective teachers' levels of scientific literacy and climate change awareness?

Chapter III

Methods

In Chapter 3, a detailed account of the method that was employed in this study is presented. This chapter outlines the research methodology, participants, procedures, data analysis method, validity and reliability, researcher’s bias and assumptions, and ethical considerations.

3.1 Study Design

The purpose of the current research was to examine the levels of scientific literacy and climate change awareness of prospective teachers in private universities in Lebanon. Moreover, this research also aimed to investigate whether there is a possible relationship between the levels of scientific literacy and climate change awareness. Specific definitions of both conceptual terms were established in Chapter 1 under “Definitions of Terms”.

The proposed research used explanatory sequential mixed method design to address the study’s research questions. Explanatory sequential research method involves a two-phase project. It is regarded sequential as the quantitative phase is followed by a qualitative phase. During the first phase, the researcher collected quantitative data using survey. During the second phase, the qualitative data was collected through interviews with the intent of explaining the quantitative results in further details.

According to Cresswell (2014), a mixed method is the integration of data from qualitative and quantitative research (p. 43). Moreover, quantitative research approach aims at testing the research objective by measuring the parameters, typically using instruments, and the data obtained is analyzed using statistical procedures (p. 33). Some of the advantages of survey designs are the economy, convenience, simplicity and the rapid turnaround in data collection (Creswell, 2014, p. 203). While the qualitative data tends to be collected through open-ended questions, such as interviews, the quantitative data is usually collected through closed-ended responses such as questionnaires (Cresswell, 2014, p. 43)

This research specifically used two survey instruments. *Test of Scientific Literacy Skills* (TOSLS), developed by Gormally et al. (2012) and available as open access for determining the levels of scientific literacy. *Awareness Scale of Climate Change* (ASCC), developed by Ezeudu et al. (2016), and available as open access for determining the levels of climate change awareness.

Correlation statistics was used to describe and measure the degree of relationship between the two parameters (Creswell, 2012) to answer research question 3.

The study adopted a cross-sectional survey design. Data was collected from September to December 2020.

3.2 Participants

In the present study, prospective teachers enrolled at teacher education programs, at private universities restricted to Beirut area were chosen. First, in the Lebanese context, some universities offer B.A. in Elementary Education to prepare homeroom teachers, other universities offer B.A. in Elementary Education and students choose their emphases, such as science and mathematics, or languages and social studies. Second, prospective teachers have a varied high school background. Some enter the teacher education programs after completing the Lebanese Baccalaureate, French Baccalaureate or a Freshmen year from Lebanese Baccalaureate; Humanities or General Science division, or after completing

American high school program, or French Baccalaureate or International Baccalaureate programs. However, during their undergraduate studies at the university, they take courses in natural sciences as well as science education. After graduation these prospective teachers will be eligible to teach science at elementary schools.

Selecting participants at different years in their programs was important to determine whether there is any statistically significant difference of levels scientific literacy and climate change awareness among the participants at different stages in their educational journey.

Participants in this study were male and female undergraduates who were enrolled in Elementary Education B.A. program. The demographic data collected was based on the following criteria: year of birth, gender, number of semester(s) at university, natural science courses taken at university, semester in which the student took the survey, science teaching methods course taken, emphasis (if exists).

The online quantitative questionnaire was sent to the chairpersons of Education Departments of four private universities, chosen based on convenience sampling. Only two universities showed interest in this research, and shared the questionnaire with the faculty, who themselves shared the link with their students (prospective teachers). Table 1 shows the total number of prospective teachers who participated in this study $n = 30$, out of which $n_1 = 2$ (approximately 7%) are males and $n_2 = 28$ (approximately 93%) are females. It should be noted that the prospective teachers were at different years in their program. While $n_3 = 2$ (approximately 7%) were first year students, $n_4 = 16$ (53%) were second year students, $n_5 = 8$ (27 %) were third year students, and $n_6 = 4$ (approximately 13%) were fourth year students. The differences in number of prospective teachers in different years at university.

Table 1. Demographics of the sample

Variable	Categories		n	%
Gender	Male		2	7
	Female		28	93
		TOTAL	30	100
Year at university	First		2	6.6
	Second		16	53
	Third		8	27
	Fourth		4	13.3
		TOTAL	30	100
Emphasis	Special Education		2	6.666
	Education		8	26.666
	Elementary Education		12	40
	Teaching Diploma		3	10
	Early Childhood Education		5	16.666
		TOTAL	30	100

Table 1 also shows the different emphasis the prospective teachers were in, with n_7 = 2 (approximately 7 %) in special education, n_8 = 8 (approximately 27 %) in education, n_9 = 12 (40 %) elementary education, n_{10} = 3 (10 %) teaching diploma, n_{11} = 5 (approximately 17 %) early childhood education.

Table 2 below shows that n_{13} = 20 (67%) of participants had not taken any science education course, n_{14} = 9 (30%) have taken one science education course.

Table 2. Science Education Courses Taken (n=number of participants)

# Science education courses taken	n	%
0	20	66.6
1	9	30
2	1	3.3
TOTAL	30	100

Table 3 below shows that n_{15} = 15 (50 %) of the participants have not taken any natural science course at university level, n_{16} = 12 (40 %) have taken one science course, n_{17} = 1 (approximately 3%) have taken two science courses, n_{18} = 1 (approximately 3%) have taken four science courses and n_{19} = 1 (approximately 3%) have taken five science courses.

Table 3. Natural Science Courses Taken at University (n=number of participants)

# Natural Science Courses taken	n	%
0	15	50
1	12	40
2	1	3.3
4	1	3.3
5	1	3.3
TOTAL	30	100

As for the qualitative interviews, the total number of participants who volunteered to participate were n = 4 out of n = 30 participants of the questionnaires.

3.3 Procedures

After acquiring IRB approval for this research, email correspondences were sent to the chairpersons of the Education Departments of private universities in Beirut region, chosen based on convenience, to inform them about the details of the research and methods of data collection. The email included the following files: “Ethical Approval Form”, “Participant Consent Form”, and an "Email to be shared with the participants” which included a link to the online survey. The participants were given four months to complete the survey. At the end of the online survey, a section was added where those participants who were willing to be interviewed, were invited to share their emails and schedules. The semi-structured interviews were conducted through Google Meet, audio-recorded to help in collecting qualitative data.

3.3.1 Surveys

Prospective teachers received emails from the administration of their departments at the universities and after their willingness to participate they followed the online link to the survey. Google Form was used as a convenience platform and ease of accessibility irrespective of the participants' schedule.

3.3.1.1 Survey Instruments

Data collection was focused on quantitative data collection using two different instruments; the use of *Test of Scientific Literacy Skills* (TOSLS) instrument which helped in collection of data in order to determine the scientific literacy levels of prospective teachers, and the use of the *Awareness Scale of Climate Change* (ASCC) which helped in determining the climate change awareness of prospective teachers.

Test of Scientific Literacy Skills (TOSLS) Instrument

For the purpose of this study, the *Test of Scientific Literacy Skills* (Appendix A) was used. The choice of this instrument is mentioned in the literature review "Instruments for measuring scientific literacy level" section. TOSLS, developed by Gormally, Brickman and Lutz (2012), is an open access psychometrically validated instrument and consists of twenty-eight multiple choice items focused on real world problems and not discipline specific. The developer's test items were examined for difficulty. In this study, the twenty-eight multiple choice items were used as is without any modification. The participants had to circle the best response to each question. Gormally et al. (2012) also divided the test items into categories and specific scientific literacy skills which were used in the data analysis of this research.

TOSLS instrument and answer key could be found in Appendix A and Appendix B.

Awareness Scale for Climate Change Instrument

For the purpose of this study, the *Awareness Scale for Climate Change Instrument* (Appendix C) was used. The choice of this instrument is mentioned in the literature review "Instruments for measuring climate change awareness level" section. ASCC is an open access instrument, designed by Ezeudu et al. (2016) on a four-Likert scale type of Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) to measure the awareness of climate change problems, facts, and general issues related on climate change.

The validity, correctness, appropriateness, clarity of the items in the ASCC instrument were ensured by three experts; two experts in Measurement & Evaluation and one expert from Geography & Environmental Education, all from the Department of Science Education, University of Nigeria, Nsukka. The instrument was piloted and the reliability was determined using Cronbach Alpha with 0.89 reliability coefficient. Although the reliability coefficient was also high for the other instruments, but this instrument had the highest Ezeudu et al. (2016).

The google form which included the consent form, and both instruments, was piloted on a sample of five first year prospective teachers. These participants were contacted and asked whether the questions were comprehensible and to ensure that there are no technical issues regarding the google form before the final survey administration. These five participants did not participate in the final study.

3.3.2 Interviews

For the purpose of this study, a semi-structured online follow-up interview was carried out during the Fall 2021 semester. The interviewees were contacted through email, to schedule the interview based on their availability. The four participants were solicited for 30-minute-interview. Each participant was shown, through screen sharing, their responses to the TOSLS survey and were asked to articulate their reasoning for their answer choices. In addition, the interviewees were asked questions regarding climate change and climate change awareness. The interviews were audio-recorded. Audio-recording was used to ensure that data analysis was based on the interviewee's responses to the questions.

Semi-structured interview questions were not strictly structured and flexibly worded. The interview was run by a list of questions, neither the exact wording nor the order was determined ahead of time. According to Merriam (2009), this format helps the researcher to guide the conversation with probing questions, with the emerging response of the respondent.

3.3.2.1 Interviewing Instrument

Appendix D includes interview questions, as an interviewing guide to lead the participant through the interview. Moreover, Appendix E includes the interview scoring rubric developed by Gormally et al. (2012). The questions in the guide are derived from the literature review, that target the research questions of this investigation.

The interview guide was divided into three sections: Demographic information, questions related to scientific literacy, and questions related to climate change awareness. The first section intended to provide demographic information regarding the participants' university and educational background. The second section aimed to provide information regarding prospective teacher's knowledge and perception of scientific literacy and its importance, which helped in answering the first research question. The third section intended to provide information regarding prospective teacher's knowledge of climate change and the importance of climate change awareness, which helped in answering the second research question.

3.3 Data Analysis Method

Both questionnaires were conducted online using Google Form, the quantitative data were analyzed using excel spreadsheet software.

The numerical data obtained from the questionnaires were organized, analyzed and presented by statistical techniques. Sheard (2018, p. 443), describes two types of statistical techniques: *descriptive statistics* and *inferential statistics* to analyze quantitative data. The *descriptive statistics* enfolds observing variations in values, and relationship between variables by presenting, for simpler interpretation of the raw data, and analyzing data through calculating the mode, mean, variance, maximum and minimum scores, range and standard deviation. While the *descriptive statistics* provides information about the immediate group of data, the *inferential statistics* helps to make a prediction about a population by studying a sample of the population for example through hypothesis testing, correlations and regression (Cohen et al., 2007, pp. 503-504).

The quantitative data analysis of the first research question was achieved through descriptive and inferential statistics techniques through analyzing the raw data obtained through *Test of Scientific Literacy Skills* questionnaire. The descriptive statistics was accomplished by calculating the average scores, median, range, mode and standard deviations of the data obtained through TOSLS instrument. The inferential statistics was used in order to check whether there is a statistically significant difference among the levels of scientific literacy of prospective teachers at different levels at university, the mean score for the levels of TOSLS of prospective teachers at different years at university, was calculated along with the standard deviation. Later, the assumption of homogeneity of variance was tested using Levene's test, before conducting a one-way ANOVA. All data were also presented in tables and graphs for ease of interpretation and analysis.

The qualitative data was obtained from the four conducted interviews. After the interviews were transcribed, the interview transcripts were read and the information were grouped based on themes, categories, and meaning units, using Gormally et al.'s (2012) indicators of scientific literacy skills below (Table 4):

Table 4. Gormally et al.'s (2012) categories of scientific literacy skills

	Theme	Categories
I	Understanding inquiry methods that lead to scientific knowledge	Identify the appropriate scientific argument Using effective literature search Evaluation in using scientific information Understanding the elements of research design and how it impacts on scientific discovery
II	Organizing, analyzing, and interpreting quantitative data and scientific information	Creating graphs that represent data Read and interpret data Problem solving using quantitative capabilities including probability statistics Understanding and being able to interpret basic statistics Presenting conclusions, predictions based on quantitative data

The two themes in Table 4, represent Goramlly et al's (2012) general themes of levels of scientific literacy. The codes were based on interview analysis. Whenever needed the prospective teachers are referred to PT1, PT2, PT3 and PT4, and PTs referring to all of them.

The quantitative data analysis of the second research question was achieved through descriptive and inferential statistics techniques through analyzing the raw data obtained through *Awareness Scale of Climate Change* questionnaire. The descriptive statistics was accomplished by calculating the average scores, median, range, mode and standard deviations of the data obtained through ASCC instrument. In order to calculate the mean and standard deviation of the raw data obtained, a numeric value or coding, was used where “Strongly agree” choice was given a value of 4, “Agree” was given a value of 3, “Disagree” was given a value of 2 and “Strongly disagree” was given a value of 1. Same analysis methodology was used in Ezeudu et al.’s (2016) and Lopez and Malay’s (2019) research articles to measure the levels of climate change awareness of high school students.

Likert scale has been widely used in research, yet during the last decades there have been ongoing discussions regarding the use of parametric statistics as a valid and robust method for analysis of non-parametric data (Feinstein, 1977; Gardner, 1975; Knapp, 1990; Kuzon, Urbanchek, McCabe, 1996). In their article, Mircioiu and Atkinson (2017) applied both parametric and non-parametric analysis to analyze a four-point Likert scale data. The authors concluded that transforming the ordinal data into binary data scores led to graphical representation and ease of further in-depth analyses.

In their paper, Ezeudu et al. (2017) used Arikunto’s (2013) criteria score interval (Table 5) to analyze their data. These criteria were also used by Utami’s (2019) study to determine the levels of scientific literacy of middle school students. Similarly, in this research Arikunto’s (2013*)* criteria (Table 5) were used to determine the levels of climate change awareness.

Table 5. Score interpretation criteria (Arikunto: 2013)

Criteria Score Interval	Criteria
80 – 100	Very good
66 – 79	Good
56 - 65	Enough
40 - 55	Low
30 - 39	Very Low

The inferential statistics was studied in order to check whether there is a statistically significant difference among the climate change awareness levels of prospective teachers at different levels at university, the mean score for the levels of ASCC of prospective teachers at different years at university, was calculated along with the standard deviation. Later, the assumption of homogeneity of variance was tested using Levene's test, before conducting a one-way ANOVA. Next, one-way ANOVA was conducted, to investigate whether the levels of climate change awareness of participants were affected by being at different years at university. All data were presented in tables and graphs for ease of interpretation and analysis.

The qualitative data for the second research question was obtained from the four conducted interviews. After the interviews were transcribed, the interview questions were categorized into two general themes: (1) *Theme 1: The knowledge of climate change* (2) *Theme 2: Prospective teachers' perception of knowledge of climate change importance and need of professional training.* Furthermore, the data were grouped under five categories (1) Prospective teachers defining climate change related terms, (2) Prospective teachers' knowledge of climate change (3) Prospective teachers' climate change awareness, (4) Prospective teachers' perception of the importance of climate change education (5) Prospective teachers' perception of the need of professional training to tackle climate change issues.

The third research question was studied through correlational statistics, Pearson's product-moment correlation coefficient, to investigate and infer what relation exists between the levels of scientific literacy and climate change awareness of prospective teachers. To that purpose, the scores obtained through TOSLS and ASCC instruments were calculated and compared by Pearson correlation coefficient (Sig. 2-tailed) at $p < 0.05$. Pearson's correlation coefficient was used to infer the strength of the association between the levels of scientific literacy and climate change awareness of prospective teachers. Data were also presented in tables and graphs for ease of interpretation and analysis.

Considering that this research study endorsed the mixed-method approach research design, it was possible to investigate the three research questions using both quantitative and qualitative data. Accordingly, the results of the two surveys were cross-checked with those obtained from interviews; the articulations of the four interviewees regarding the scientific literacy questionnaire and climate change awareness related interview questions. The data was triangulated. The intent was to validate the results of the questionnaire and try to confirm the obtained hypotheses regarding the low level of scientific literacy and the significant level of climate change awareness of participants.

Both instruments, TOSLS and ASCC were obtained from the reviewed literature, thus the validity of the research study is increased. According to Walonick (2005) content validity is enhanced when reviewing the literature and using instruments which cover the research questions. In addition, both instruments were piloted to ensure the validity and reliability of the instrument in the context of the study. Herein, it should be noted that for ASCC instrument, item number 9, was modified to "There is a decrease in agricultural products in *Lebanon*" to fit the cultural context.

The reader decides whether the results are applicable to his / her context (Merriam, 2009). To help the reader to compare the findings with his / her context, the researcher presented a detailed description of the context of the study and the procedures. Therefore, a holistic descriptive presentation of the findings is provided.

Chapter IV

Findings

Chapter 4 presents the descriptive and inferential analysis of the findings obtained from the quantitative instruments, *Test of Scientific Literacy Skills* (TOSLS) and *Awareness Scale of Climate Change* (ASCC), to answer each of the three research questions. Thereafter, the findings from the qualitative interviews are reported and analyzed. The chapter ends with "Summary of the Findings of the Interviews" and "Overall Findings".

4.1 Quantitative Data Analysis

4.1.1 Quantitative Data Analysis for Test of Scientific Literacy Skills Instrument

To calculate the central tendency and measures of dispersion of data, the total number of correct answers were used as raw data. Each correct answer was given a value of 1 out of 28. Later, the mean, median, and mode were calculated as representation of central tendency, and standard deviation and variance were calculated as measures of dispersion of data. The results are presented in Table 6.

Table 6. Descriptive statistics of the levels of scientific literacy of n = 30 prospective teachers.

Mean	Median	Mode	SD	Minimum	Maximum	Variance
11.75	11.50	10.00	4.015	4	19	16.120

The descriptive statistical analysis of Table 6 indicates that the mean score of approximately 12 (approximately 42%), according to Arikunto's criteria (2013) (Table 5), the prospective teachers have low levels of scientific literacy.

The median approximately 12 indicates that the data are symmetrical and appear to be slightly skewed to the right, which explains why the mean is slightly greater than the median. With median approximately 12 indicates that half of the data obtained are greater than 11.50 and half the data obtained are less than 11.50.

The most frequent data related to scientific literacy is indicated by the mode 10.00. The data also shows that the lowest mean score level of scientific literacy scored by prospective teachers was 4 and the highest was 19 out of 28. A SD 4.015 shows that data are scattered around the mean. Variance 16.120 indicates that the average of all data points is spread out from the mean approximately 12.

Further analysis was conducted to compare the mean scores of each of the 28 questions of TOSLS instrument, of the participants (n = 30), a bar graph was drawn in Figure 1.

Figure 1. A bar graph showing the mean scores achieved by the prospective teachers (n= 30) for the 28 questions of the TOSLS instrument.

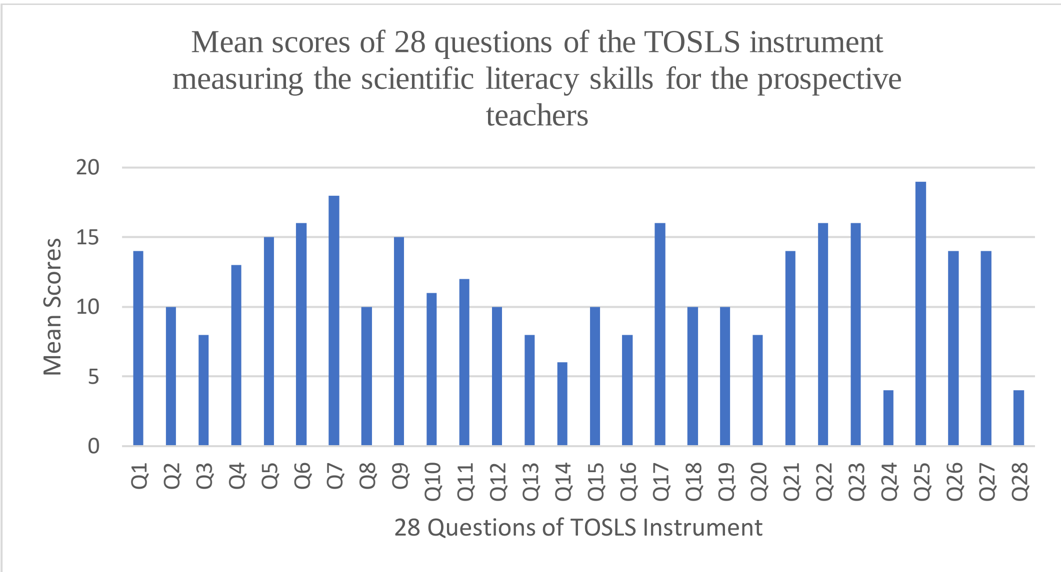


Figure 1 shows, the highest mean score 19 was for Q25 and the lowest mean score of 4 was for that of questions Q24 and 28.

Overall, the bar graph shows that prospective teachers (n = 30) showed varied mean scores in regards to the 28 questions of the TOSLS. Hence, to determine the general levels of scientific literacy of prospective teachers, the data obtained in Table 7 (Appendix F), was used to calculate the percentages, and analyzed, based on Arikunto’s (2013) score interpretation criteria.

Table 7. Percentage of criteria score obtained from 28 TOSLS instrument questions.

Criteria	Frequency of responses	Percentage
Very good	0	0
Good	2	7
Enough	4	14
Low	8	29
Very Low	14	50
TOTAL	28	100

As seen in Table 7 none of the participants ranked “very good” scientific literacy level, and most ranked in “very low” criteria n= 14 (50 %), followed by n= 8 (29 %) ranked in “low”.

To further analyze the data, a bar graph was plotted (Figure 2) depicting the mean scores of the data obtained from the 28 questions of the TOSLS instrument were grouped by skills (Table 9) as determined by Gormally et. al (2012).

Figure 2. Bar graph showing the mean scores of each question grouped based on the skills of the 28 questions of TOSLS instrument.

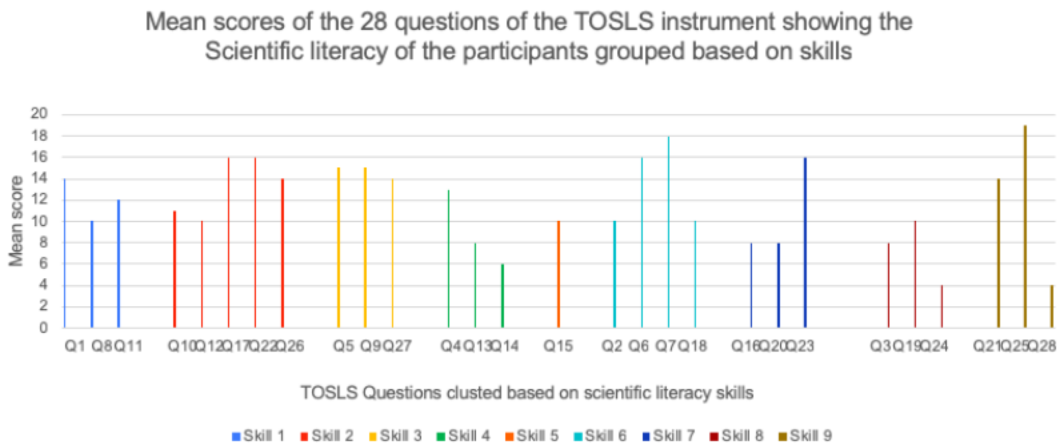
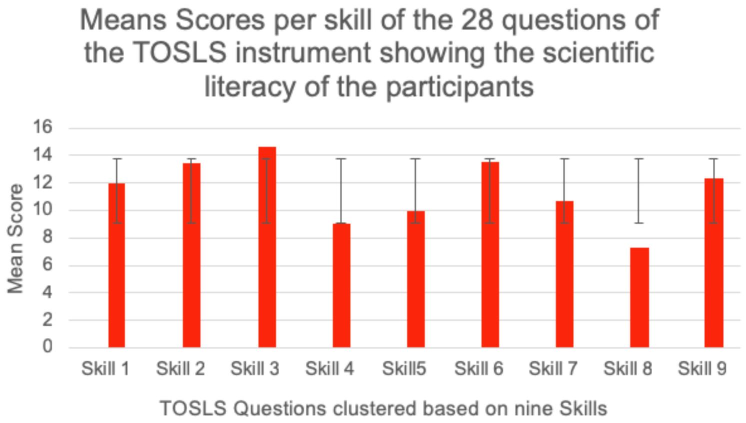


Figure 2 illustrates all skills have questions with mean scores below that of the overall mean score of approximately 12 (Table 6). Hence, to visualize which skill has a low overall mean score, a bar graph (Figure 3) was drawn with the mean scores of each skill.

Figure 3. Bar graph showing the mean scores of each question grouped based on the skills of the 28 questions of TOSLS instrument.



It could be inferred, from Figure 3 above, that the lowest scientific literacy scores were associated with skills related to quantitative aptitude and scientific reasoning. Skills related to quantitative aptitude: (1) Creating graphs, skill 5 (mean score 10) (2) Solving problems, skill 7 (mean score approximately 11), and (3) Understanding and interpreting basic statistics skill 8 (mean score approximately 7). Skills related to scientific reasoning: (1) Understanding essential elements of research design skill 4 (mean score 9). Participants also demonstrated relatively high abilities in skill 3 Evaluating the use and misuse of scientific information. The standard deviation bars are overlapping which indicates that the difference is not statistically significant. This was further analyzed using inferential statistics.

To determine whether the levels of scientific literacy for the four different participant groups are different, Table 8 was drawn which includes the mean scores and standard deviation analysis. The maximum number to be attained for each correct answer, for each of 28 questions of TOSLS instrument, is 1.

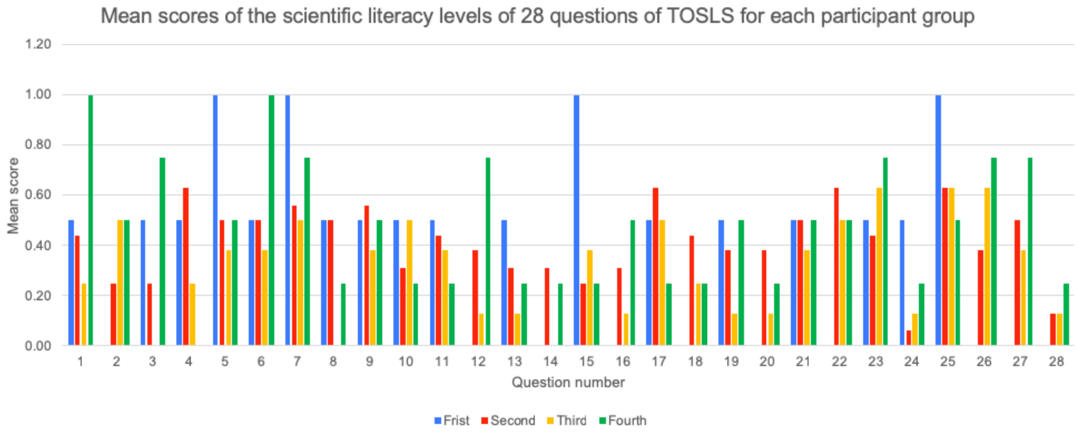
Table 8. Result of mean scores and standard deviation analysis of the levels of scientific literacy based on 28 questions of the TOSLS instrument according to participants' year at university

	First Year		Second Year		Third Year		Fourth Year	
Question Number	Mean score	SD	Mean score	SD	Mean score	SD	Mean score	SD
1	0.50	0.71	0.44	0.51	0.25	0.46	1.00	0
2	0	0	0.25	0.45	0.50	0.53	0.50	0.58
3	0.50	0.71	0.25	0.45	0	0	0.75	0.50
4	0.50	0.71	0.63	0.50	0.25	0.46	0	0
5	1.00	0	0.50	0.52	0.38	0.52	0.50	0.58
6	0.50	0.71	0.50	0.52	0.38	0.52	1.00	0
7	1.00	0	0.56	0.51	0.50	0.53	0.75	0.50
8	0.50	0.71	0.50	0.52	0	0	0.25	0.50
9	0.50	0.71	0.56	0.51	0.38	0.52	0.50	0.58
10	0.50	0.71	0.31	0.48	0.50	0.53	0.25	0.50
11	0.50	0.71	0.44	0.51	0.38	0.52	0.25	0.50
12	0	0	0.38	0.50	0.13	0.35	0.75	0.50
13	0.50	0.71	0.31	0.48	0.13	0.35	0.25	0.50
14	0	0	0.31	0.48	0	0	0.25	0.50
15	1	0	0.25	0.45	0.38	0.52	0.25	0.50
16	0	0	0.31	0.48	0.13	0.35	0.50	0.58
17	0.50	0.71	0.63	0.50	0.50	0.53	0.25	0.50
18	0	0	0.44	0.51	0.25	0.46	0.25	0.50
19	0.50	0.71	0.38	0.50	0.13	0.35	0.50	0.58
20	0	0	0.38	0.50	0.13	0.35	0.25	0.50
21	0.50	0.71	0.50	0.52	0.38	0.52	0.50	0.58
22	0	0	0.63	0.50	0.50	0.53	0.50	0.58
23	0.50	0.71	0.44	0.51	0.63	0.52	0.75	0.50
24	0.50	0.71	0.06	0.25	0.13	0.35	0.25	0.50
25	1	0	0.63	0.50	0.63	0.52	0.50	0.58
26	0	0	0.38	0.50	0.63	0.52	0.75	0.50
27	0	0	0.50	0.52	0.38	0.52	0.75	0.50
28	0	0	0.13	0.34	0.13	0.35	0.25	0.50
AVERAGE	0.39		0.41		0.31		0.47	

Data analysis in Table 8 showed that the highest overall scientific literacy mean score is to that of prospective teachers in fourth year is 0.47 and the lowest overall scientific literacy mean score is to that of prospective teachers in third year is 0.31.

A bar graph representing the mean scores of the participants is represented in Figure 4.

Figure 4. Bar graph showing the mean scores achieved by participants of each four groups (n=30) based on 28 questions of TOSLS instrument.



A descriptive statistical analysis of the obtained data for the 28 questions of TOSLS instrument indicates that the mean score of the first-year participants range between 0 and 1, that of the second-year participants between 0.06 and 0.63, while that of the third-year participants between 0 to 0.63 and the fourth year between 0 to 1. This means that the smallest range of the mean scores is for that of the third-year participants.

The levels of scientific literacy of participants at different years at university was studied through calculating the average scores and the standard deviation achieved of 28 questions of TOSLS instrument. The results are shown in Table 9.

Table 9. Participants' mean score of scientific literacy levels according to year at university

Year at University	n	% of participants	Mean score	SD
First	2	6.6	11	1
Second	16	53	12	5
Third	8	27	9	4
Fourth	4	13.3	13	2
TOTAL	30	100		

The standard deviations in Table 9 do not represent the average of all the standards achieved by the different questions in a specific year at university, but rather, it is the standard deviation of all the mean scores achieved by the 28 questions.

The results indicate that the highest sample size is from participants who are second year at university, followed by the third and first and fourth year students have same percentage. The lowest mean score was that of the third-year participants (9), the mean scores of the first and second-year students are similar (12), followed by the highest for the fourth-year students (13). As for the standard deviations obtained for the four participant groups, it can be inferred that the lowest standard deviation was that of the first year and the highest that of the second-year students.

In order to show whether the levels of scientific literacy of prospective teachers at different years at university was different, the assumption of homogeneity of variance was tested using Levene's test, before conducting one-way ANOVA. The **hypothesis** for Levene's test being:

H_0: The four groups of participants have equal population variance.

H_A: The four groups of participants do not have equal population variance.

The statistical data generated was tabulated in the Table 10.

Table 10. Levene's test results for equality of variances of levels of scientific literacy based on 28 items of the TOSLS instrument according to participants' year at university

Source of Variation	SS	df	MS	F	P-value
Between Groups	37.242	3	12.414	3.459	0.0307
Within Groups	93.313	26	3.589		
TOTAL	130.554	29			

Analyzing the results of Levene's test for the homogeneity of variance showed that since p < .05 fail to reject the null hypothesis, which states that the variances are the same in all groups. In other words, we cannot assume that the variances are the same. However, due to the robust nature of ANOVA to violations, one-way analysis of variance (ANOVA) was conducted to investigate whether the levels of scientific literacy of prospective teachers at different years at university are different. The levels of significant was set to 0.05.

Table 11. One-way ANOVA of mean scores of levels of scientific literacy according to year at university

	Sum of squares	df	Mean square	F	P-value
Between Groups	70.404	3	23.468	1.234	0.317
Within Group	494.562	26	19.022		
Total	564.967	29			

One-way ANOVA revealed that F (3, 26) = 1.234, p > .05. Null hypothesis is not rejected. Given these results, it could be inferred that there are no statistically significant differences among the levels of scientific literacy of prospective teachers at different years at university at α = .05 significance level.

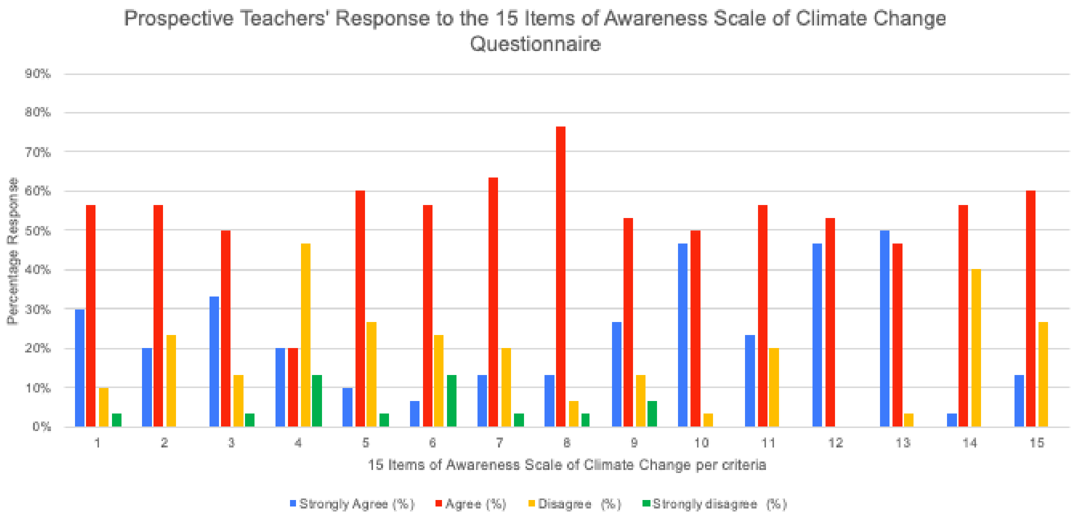
4.1.2 Quantitative Data Analysis for Awareness Scale of Climate Change Instrument

The data obtained from *Awareness Scale of Climate Change Instrument*, is based on a 4-point Likert scale ranging from "Strongly Agree" on one end, to "Strongly disagree" on the other, where no indifferent option available, hence the participants were forced to choose from four answer choices to express their degree of agreement with a particular statement. Table 12 represents the frequency of the responses.

Table 12. The percent data of participants' degree of agreement for an item.

		Strongly Agree	Agree	Disagree	Strongly Disagree	TOTAL
Item 1	#	9	17	3	1	30
	%	30	57	10	3	100
Item 2	#	6	17	7	0	30
	%	20	57	23	0	100
Item 3	#	10	15	4	1	30
	%	33	50	13	3	100
Item 4	#	6	6	14	4	30
	%	20	20	47	13	100
Item 5	#	3	18	8	1	30
	%	10	60	27	3	100
Item 6	#	2	17	7	4	30
	%	7	57	23	13	100
Item 7	#	4	19	6	1	30
	%	13	63	20	3	100
Item 8	#	4	23	2	1	30
	%	13	77	7	3	100
Item 9	#	8	16	4	2	30
	%	27	53	13	7	100
Item 10	#	14	15	1	0	30
	%	47	50	3	0	100
Item 11	#	7	17	6	0	30
	%	23	57	20	0	100
Item 12	#	14	16	0	0	30
	%	47	53	0	0	100
Item 13	#	15	14	1	0	30
	%	50	47	3	0	100
Item 14	#	1	17	12	0	30
	%	3	57	40	0	100
Item 15	#	4	18	8	0	30
	%	13	60	27	0	100

Figure 5. The degree of agreement of participants to each of the 15 items of ASCC instrument



In order to calculate the mean and standard deviation of the raw data obtained, a numeric value or coding, was used as mentioned in Chapter 3. Later an aggregate of the number of responses for each Likert level, in each item, was used without differentiating between the participant answers of different years at university. Hence the raw data was changed from ordinal scale into a numerical scale, which led to the calculation of mean and standard deviation of each item, as seen in Tables 13 and 14.

Table 13. Provides the mean and standard deviation of each item based on the participants' response.

Item	SA	A	D	SD	Mean	SD
1	9	17	3	1	3.133	2.683
2	6	17	7	0	2.967	2.503
3	10	15	4	1	3.133	2.696
4	6	6	14	4	2.467	2.129
5	3	18	8	1	2.767	2.309
6	2	17	7	4	2.567	2.160
7	4	19	6	1	2.867	2.408
8	4	23	2	1	3.000	2.517
9	8	16	4	2	3.000	2.582
10	14	15	1	0	3.433	2.944
11	7	17	6	0	3.033	2.569
12	14	16	0	0	3.467	2.966
13	15	14	1	0	3.467	2.978
14	1	17	12	0	2.633	2.145
15	4	18	8	0	2.867	2.394

Table 14. Result of mean and mode analysis of the climate change awareness of prospective teachers.

Item	Median	Mode	Decision
1. Climate is dynamic and always changing through natural cycle.	3.133	10.333	Agree
2. Climate change is a measurable increase in the average temperature of earth's atmosphere.	2.966	9.233	Agree
3. Change in weather condition over an extended period of time is climate change.	3.133	2.695	Agree
4. Climate change is characterized with high temperature.	2.466	2.129	Disagree
5. Climate change comes with a rise in sea level.	2.766	2.309	Agree
6. Climate change is characterized by desertification.	2.566	2.160	Agree

7. Most streams in hinterland are drying up as a result of climate change.	2.866	2.408	Agree
8. There is an observed increase in sea level in the coastal areas.	3.000	2.516	Agree
9. There is decrease in agricultural products in Lebanon.	3.000	2.581	Agree
10. I have heard of climate change before.	3.433	2.943	Agree
11. The rate of sunshine is higher now than before.	3.033	2.569	Agree
12. The weather seems to be hotter nowadays.	3.466	2.966	Agree
13. The atmospheric heat level is higher now than before.	3.466	2.977	Strongly Agree
14. There is an increased rate of rainfall.	2.633	2.144	Agree
15. Cases of flooding occur more nowadays.	2.866	2.394	Agree
TOTAL	2.987		

The result of data analysis in Table 14 showed that the overall climate change awareness mean score of prospective teachers is 2.987 which is above the mean benchmark value of 2.50 (Ezeudu et al. 2016, described a mean score of 2.50 as the benchmark value of the four-point scale). This result indicates that the prospective teachers possess high climate change awareness.

The mean scores and standard deviation of levels of climate change awareness per year at university was calculated and presented in Table 15.

Table 15. Mean scores and standard deviations of climate change awareness level based on 15 questions of the ASCC instrument according to participants' year at university.

	Mean	Standard Deviation
First Year	2.833	.800
Second Year	3.004	.681
Third Year	3.008	.661
Fourth Year	2.950	.456

A bar graph representing the mean scores of the participant groups to visualize the data was drawn in Figure 6.

Figure 6. Mean score of levels of climate change awareness of participants (n=30) at different years at university

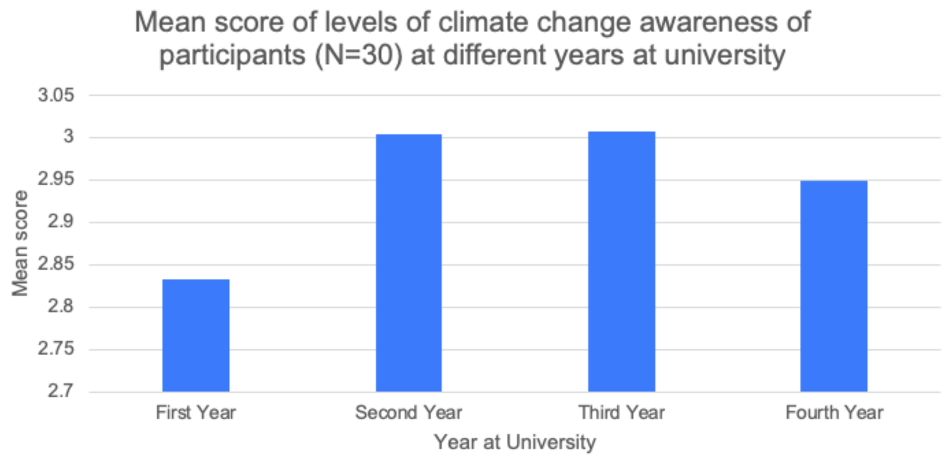


Figure 6 depicts the comparison of mean score of levels of climate change awareness based on the four participant groups. The mean score of the first-year participants being the lowest. The mean scores of third year participants slightly higher than that of the second-year participants.

To further investigate, if there exists a statistically significant difference among climate change awareness levels of prospective teachers at different years at university, descriptive and inferential statistics were performed. Following descriptive statistics, the assumption of homogeneity of variance was tested using Levene's test, before conducting one-way ANOVA. The **hypothesis** for Levene's test being:

H_0: The four groups of participants have equal population variance.

H_A: The four groups of participants do not have equal population variance.

The statistical data generated was tabulated in the Table 16.

Table 16. Levene's test results for equality of variances of levels of climate change awareness level based on 15 items of the ASCC instrument according to participants' year at university

Source of Variation	SS	df	MS	F	P-value
Between Groups	58.851	3	19.6172	209.352	2.1409E-30
Within Groups	5.247	56	0.093		
TOTAL	64.099	59			

Leven's test showed that the variances for climate change awareness level of participants at different years at university were not equal, since $p < .05$. In other words, we cannot assume that the variances are the same. However, due to the robust nature of ANOVA to violations, one-way analysis of variance (ANOVA) was conducted. One-way ANOVA was run to determine whether there is a statistically significant differences between the means of the levels of climate change awareness of participants at different years at university.

The results are depicted in Table 17.

Table 17. One-way ANOVA of mean scores of levels of climate change awareness according to year at university

	Sum of squares	df	Mean square	F	P-value
Between Groups	0.299	3	0.099	0.499	0.684
Within Group	11.188	56	0.199		
Total	11.488	59			

The one-way ANOVA revealed that F (3, 56) = 0.499, $p > .05$, there are no statistically significant differences in levels of climate change awareness between the four participant groups.

4.1.3 Quantitative Data Analysis for Research Question 3

The relationship between levels of scientific literacy and climate change awareness of prospective teachers was investigated using Pearson product-moment correlation coefficient. The level of significance was set to 0.05. Table 18 summarizes the statistics related to the correlation.

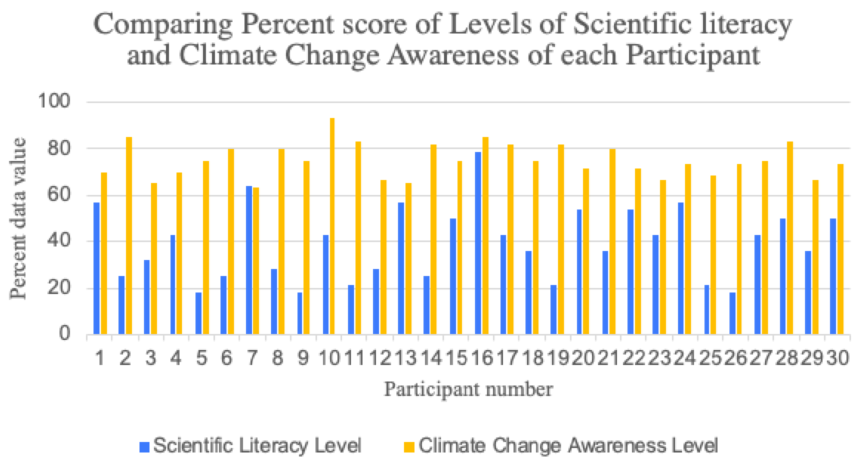
Table 18. Pearson product-moment correlations between levels of scientific literacy and climate change awareness

Correlations		Scientific literacy levels (SL levels)	Climate Change Awareness Levels (CCA levels)
SL level	Pearson Correlation	1	-.145
	Sig. (2-tailed)		.445
	n	30	30
CCA levels	Pearson Correlation	-.145	1
	Sig. (2-tailed)	.445	
	n	30	30

Results in Table 18 showed that with the Pearson correlation coefficient, r= -.145 < .05 there is a weak negative correlation between the levels of scientific literacy and climate change awareness of prospective teachers.

To visualize the result obtained from Pearson product-moment correlation coefficient a bar graph (Figure 7) was used to show the relationship between levels of scientific literacy and climate change awareness data sets.

Figure 7. Bar graph showing the percent score of levels of scientific literacy and climate change awareness of each participant



The bar graph above shows the climate change awareness levels of all participants are higher than the scientific literacy level, except in participant 7 where the levels of scientific literacy and climate change awareness are almost the same.

Overall, the results of the Pearson correlation indicated that there is a weak negative correlation (r= -.145 < .05) between the levels of scientific literacy and climate change awareness.

4.2 Qualitative Data Analysis

The first part of this section will analyze the results related to the interviewees' articulation of their TOSLS instrument answers. The second part will be related to the four interviewees' answers to the climate change interview questions.

4.2.1 Qualitative Data Analysis Regarding the Levels of Scientific Literacy

Theme 1: Understand methods of inquiry that lead to scientific knowledge

In this theme, derived from Gormally et. al's (2012), the data collected were grouped into four categories, based on Gormally et. al's (2012) categories, which are (1) *Identify a valid scientific argument*, (2) *Evaluate the validity of sources*, (3) *Evaluate the use and misuse of scientific information*, (4) *Understand elements of research design and how they impact scientific findings / conclusions.*

In the first category, *identify a valid scientific argument*, which comprises of questions 1, 8 and 11, none of the interviewees could answer all three questions correct. This could be interpreted as interviewees have difficulty in linking claims to scientific evidence. The interviewees' articulation showed that they chose the answers based on common key terms that appear in scientific arguments for example "temperature" and "numbers". "I felt that it is a valid scientific argument because since they spoke about temperatures in the US. I felt that it was more scientific related" (PT1, personal interview, December 12, 2020). Two other interviewees focused on numbers "I don't know I thought when you say that what people said and what people experience is more accurate. But I should have looked more on statistics (PT2, personal interview, December 11, 2020). Further another interviewee "the one

I selected is more of just a poll that revealed that "34 percent" it's not something I can argue" (PT3, personal interview, December 12, 2020).

Regarding the second category, *Evaluate the validity of sources,* which includes questions 10, 12, 17, 22 and 26, two interviewees could answer 4 correct out of 5. The other two interviewees were unable to identify accuracy and credibility of sources provided. When PT3 was asked to articulate the reasoning behind the answers it was described this way "at university we're always asked to include references in our …what we write, so I feel like … now when I think about it, if I see that there is a reference somewhere that is perfectly cited the way we're supposed to cite and it is accurate because of the information that I'm supposed to be reading" (PT3, personal interview, December 12, 2020). "The information was very brief and very direct like it was showing to me the bigger spec of something" (PT3, personal interview, December 12, 2020).

With reference to the third category, *Evaluate the use and misuse of scientific information,* which includes questions 5, 9 and 27, overall the interviewees had difficulty recognizing a valid and ethical scientific course of action and use of science free of bias to make informed societal decisions. In this regard an interviewee expressed "Here comes the philosophical side between experiment and proving it wrong, then proving it right, and stuff" (PT2, personal interview, December 11, 2020). Still another interviewee had an interesting articulation "Journalists cannot really validate what scientists do honestly, more the scientists would do that and research and empirical evidence because this is the nature of science" (PT3, personal interview, December 12, 2020).

In connection with category four, *Understand elements of research design and how they impact scientific findings / conclusions,* which includes questions 4, 13 and

14, all four interviewees had difficulty answering the related questions. This overall shows the lack of understanding of important elements of a good research design. An articulation from a third-year interviewee, who struggled answering the question, “I thought this was the more accurate answer compared to the other answers. I don’t think fertilizers are accurate. I cancelled out basically” (PT2, personal interview, December 11, 2020). “I don’t really remember but I think it’s about the large sample size or not randomly of course. I don’t think randomly helps in the strength of the study” (PT2, personal interview, December 11, 2020).

Theme 2: Organize, Analyze, and Interpret Quantitative Data and Scientific Information

In this theme, derived from Gormally et. al’s (2012), the collected data were grouped based on Gormally et. al’s (2012) five main categories (1) *Create graphical representations of data*, (2) *Read and Interpret graphical representations of data,* (3) *Solve problems using quantitative skills including probability and statistics*, (4) *Understand and interpret basic statistics,* (5) *Justify inferences, predictions, and conclusions based on quantitative data.*

The first category *Create graphical representations of data*, which includes question 15, three out of four interviewees were able to accurately identify the appropriate type of graph for data representation. Interestingly some of the interviewees refer to the courses they have taken and how they have used their acquired knowledge to answer the questions.

Some of the interviewee's articulations: "This is also from statistics course, if you want to display an average you usually use graph D" (PT1, personal interview, December 12, 2020). "I am horrible with graphs. I really have a hard time reading graphs. But I think it is the semi-circle. Graph B" (PT2, personal interview, December 11, 2020). " I chose graph D, because when we study averages, we look at something called a histogram, I'm not sure if it is a histogram, so maybe when I read the words mean … and also the pie chart is associated with percentages so I didn't really look at pie charts although it has two variables" (PT3, personal interview, December 12, 2020).

From the above and interview articulations it is evident that although three of four interviewees could identify the right format of the graph for the data given, yet they express the difficulty in identifying the right format of graph. Interestingly, PT1 and PT2 refer to their statistical knowledge from the courses they have taken at university level.

In regards to category two, *Read and Interpret graphical representations of data*, which includes questions 2, 6, 7, and 18, all four interviewees had difficulty in interpreting the graphs and deciding based on data given whether the growth is exponential or linear. Some of interviewees articulation in this regard are: "Here I got a bit lost because it wasn't divided into 10 years every single time that's why I answered that it doubles every 20 years" (PT1, personal interview, December 12, 2020). Another interviewee responded "I'm not near graphs as of understanding. But I thought that the A represents what the table had going back to the economic background I had" (PT2, personal interview, December 11, 2020). Still another interviewee articulated "I looked at all of them and I thought they are the same. So, I thought they are the same. So, I randomly chose 1" (PT4, personal interview, December 12, 2020). Overall, interviewees showed difficulty in comprehending data presented graphically and making a valid conclusion of a scientific study.

With respect to category three, *Solve problems using quantitative skills including probability and statistics,* which includes questions 16, 20 and 23, interviewees showed difficulty in performing basic mathematical calculations such as probabilities, percentages, and frequencies in order to draw a conclusion of data given. Interestingly, interviewees also shared statements of low self-efficacy, words like "I think", "I guess" and "I'm not sure" "right?" were used. Some of the articulations made: "I faced difficulty in the calculations maybe because there's percentages the problem is that I found that the three results in three different ways. So, I was really confused" (PT1, personal interview, December 12, 2020). "Here I think I did since there are 5% of falsely positive I felt I should deduct 1 - 5 /100, and I take 10,000 - no sorry x (1-5/100) I got 500" (PT1, personal interview, December 12, 2020). Another interviewee stated "I wrote the answer inversely. It should be 40% right? I thought the answer is what percentage is left, dead …. I did 100 and these are 60 gone" (PT2, personal interview, December 11, 2020). While another articulated "I have an issue with percentages. … (inaudible) …. I guess I used a calculator and got 35. I'm not so good with percentages" (PT2, personal interview, December 11, 2020). Still another interviewee had a hard time calculating, "because the number of rats was not mentioned in this question and I couldn't calculate. I couldn't calculate how many rats were there after" (PT4, personal interview, December 12, 2020).

In regards of category four, *Understand and interpret basic statistics, Justify inferences, predictions,* which includes questions 3, 19 and 24, from the results of survey questions overall the interviewees showed difficulty in familiarity with statistical analysis and understanding of scientific uncertainty. One interviewee stated

“I was a bit uncertain regarding if it’s smaller or larger I was tricked by the fact that they used 25 bottles here and 100 bottles there” (PT1, personal interview, December 12, 2020). Another interviewee mentioned “I still don’t really understand the question. But I will look at the answers again … I can’t see the information unless in a graph. I need to see exactly where they are written” (PT2, personal interview, December 11, 2020). . While another articulated “the reason I chose the (third choice) is also because of exposure in school and stuff like, we’ve been always exposed to “calculate the mean”, “solve the mean”, “find mean” so it is always like this, so you have this direct instinct, hey I haven’t been exposed to this for a very long time and I’ll just choose this because that’s what we always do. “The average” or “The mean” (PT3, personal interview, December 12, 2020).

In reference to category five, *Justify inferences, predictions, and conclusions based on quantitative data,* which includes questions 21, 25 and 28, overall there was a higher tendency of interviewees to misinterpret data, experimental designs or evaluate an argument. This was also articulated during interview, as one of the interviewees articulated “I honestly could not really explain how it happened so I assume that from their nature the shrimps could be more abundant in places where they could swim deeper but I wasn’t really sure” (PT1, personal interview, December 12, 2020). Further another interviewee vocalized “I didn’t really get the graph and the options” (PT3, personal interview, December 12, 2020). While another interviewee disclosed “I chose this graph can’t be interpreted because I couldn’t interpret it. I chose this graph can’t be interpreted because I couldn’t interpret it” (PT4, personal interview, December 12, 2020).

In conclusion, the four interviewees had various challenges in regards to: (1) identifying important elements of scientific research design (2) identifying appropriate use of scientific data, evidence and information by for example governments, media and industry away from any political pressures (3) linking claims to scientific evidence (4) difficulty in critical observations (5) finding the correct answer choice through relying on frequently used terms in science books and during courses such as: “temperature”, “numbers”, “find mean”, “solve the mean” instead of analyzing the data given based on scientific content knowledge, scientific thinking, reasoning and observation (6) interpreting data presented in the form of graphs, and numerical data given to make conclusion (7) basic mathematical calculations such as frequencies, percentages and probabilities. Interestingly, the interviewees used words like “I think”, “I guess”, “right?” which shows low self-efficacy.

4.2.2 Qualitative data analysis regarding the level of climate change awareness

In regards to climate change awareness representing the qualitative data collected (Appendix G), the data were categorized under two general themes:

Theme 1: The knowledge of climate change

Theme 2: Prospective teachers’ perception of knowledge of climate change importance and need of professional training

Furthermore, the data were grouped under five categories (1) Prospective teachers defining climate change related terms, (2) Prospective teachers’ knowledge of climate change (3) Prospective teachers’ climate change awareness, (4) Prospective teachers’ perception of the importance of climate change education (5) Prospective teachers’ perception of the need of professional training to tackle climate change issues.

Theme 1: The knowledge of climate change

In this theme the categories included are: (1) Prospective teachers defining climate change related terms, (2) Prospective teachers' knowledge of climate change (3) Prospective teachers' climate change awareness.

Regarding the first category, interviewees' knowledge of climate change, the 4 interviewees showed significant ability to define climate change related terms. Herein, I present some of interviewees' verbalizations: "**Global warming** an extra heating of the planet due to the pollution that is affecting the layer of ozone, and making UV rays more …. first the UV rays for people become more threatening and affects the environment, the ecology, the weather and it affects everything on earth basically" (PT1, personal interview, December 12, 2020). "**Climate change** is basically the change in the weather over a very long period of time due to environmental changes that happen in our habitat or ecosystem. And also, on the spec of worldwide climate change not just country" (PT3, personal interview, December 12, 2020). **"Climate change awareness,** knowing that climate change happens because of humans … it is in our hands that climate change is happening due to pollution, due to the way we are treating the sea. So, it is important for us to know and be aware that climate change is happening, and it is also important for us to know that climate change is not a small thing. It should be emphasized that it's in fact over long period of time. So, if you keep doing this it's gonna affect our lives. We are destroying our lives basically. We should know to what extreme level climate change is" (PT3, personal interview, December 12, 2020).

Regarding the second category, *Prospective teachers' knowledge of climate change*, interviewees showed significant level of knowledge of climate change, including referral and awareness of the anthropogenic effects that lead to climate change. Some of participants' verbalizations in this regard are: "some aspects of climate change are rise of sea levels, ocean levels, there is lack of rain maybe and a third one I would say maybe desertification and heat" (PT1, personal interview, December 12, 2020). "Climate change is usually a natural phenomenon it happens but humans could alter it with wrong actions to the environment that would affect the cycle. Neglect to ecology by humans like infrastructures are affecting the climate highly and reflecting on us at the end" (PT1, personal interview, December 12, 2020). Another interviewee added "the climate is changing. My sister lives in Canada and the temperature rises and falls everyday basically. One day it is snowing the other day it is hot. I'm just looking at her this is definitely climate change. And I saw the pictures that the snow is melting" (PT2, personal interview, December 11, 2020). While another interviewee also identified the importance of plants "humans causing the climate change because I believe that nature changes itself and nature is the producer of life. Without plants we are nothing. So that's why we are the reason that there is climate change. Because we are polluting and we are doing all the stuff" (PT3, personal interview, December 12, 2020). "Climate change is not happening naturally. We are causing climate change. Factories, cars, cutting trees, that's all I can think of. We should plant more trees, shut down a few factories" (PT4, personal interview, December 12, 2020).

Regarding the third category, *Prospective teachers' climate change awareness*, participants expressed that the interaction of "experience", "attention" and "knowledge" define climate change awareness. Some of participants' verbalizations in this regard are: "These three are very strong elements not only climate change but anything if we don't have the right knowledge and don't understand it's severity if one of them is lacking we can't really act on it or feel the need to relate to it or do something about it" (PT1, personal interview, December 12, 2020), PT1 also added "Climate change is always part of our life on earth so it should remain part of something we learn about and stay informed of it. If hopefully it is fixed we also benefit from keeping it and maintaining it this way." "Because everyone can contribute in his own way as long as they are rational and are capable of doing something, because it is everybody's problem and not they shouldn't be saying it is known of my business". While PT2 also called for action by different stakeholders in PT2's words "make the people who do not believe in climate change, to know it is an actual thing, so raising awareness. Each individual should take little steps, consume less, these will help in a change even if it is minor." "Awareness should always be implemented. I think governments should do something about it, NGOs, social workers they should implement and not only raise awareness" (PT2, personal interview, December 11, 2020). On the other hand, PT3 specifies need to relate knowledge into real life situations, in PT3's words, "I keep saying experience but you can experience stuff and you have the knowledge about it but you need someone to relate it to real life situation, you need someone to give you the actual scientific knowledge of it. And not just knowledge through media and stuff." PT3 identifies various stakeholders, in PT3's vocalization "the stakeholders of this awareness of climate change are parents, teachers because children spend most of their time with their teachers and parents, and hence shape the child's minds. And the concept of climate change is not one day thing it is being environmentally friendly is a habit it is something you learn. And also, to make it possible, and accessible and we should have a government that actually acknowledges such things" (PT3, personal interview, December 12, 2020). PT4 called for action "It is not enough to be knowledgeable about the subject but one has to act and exert some kind of change" (PT4, personal interview, December 12, 2020).

Theme 2: Prospective teachers' perception of knowledge of climate change importance and need of professional training

In this theme the categories included are: (1) Prospective teachers' perception of the importance of climate change education (2) Prospective teachers' perception of the need of professional training to tackle climate change issues.

Regarding the first category, *Prospective teachers' perception of the importance of climate change education*, participants expressed due to anthropogenic nature of climate change, hence the need to incorporate it in education, by pinpointing age-specific instruction. In this regard PT1 commented "In terms of the Lebanese since it is one of our biggest problems in terms of pollution that is causing it, I feel that starting with the simplification over the term but starting at a young age is very important since the children can have this sort of (inaudible) that can help them understand the situation and slowly understand them gradually and even be interested in it as long as it is presented in a way that gets their interest and at the same time and makes them want to do something for their country and even for their planet", "All topics can be thought at elementary but more simplified so students can understand it, maybe present it in ways like in plays, or movies for their age but what matters is that they understand the seriousness of the situation" (PT1, personal interview, December 12, 2020). On the other hand, PT2 referred to some of the stakeholders as well, in PT2's words "Maybe the teachers and the principals and students should understand that everyone surrounding them supports this idea and not only the teacher or someone specific because it is everyone's problem. Climate change could be taught in any course as long as the concept is there. It could be taught at any level the details covered could be different and even certain specifications", "Being a future teacher, I think as small as KGs they should know about recycling, I would really like to incorporate it into my class. It would be very important" (PT2, personal interview, December 11, 2020). Moreover, PT3 refers to the implementation of the knowledge attained in everyday life, in PT3 words "it should be taught from childhood. The exposure should be from kindergarten to adulthood. And not only taught only theoretically. No, it should be implemented like in daily life. You should give solutions to the students. Like don't just tell them that factories should stop emitting … I mean I can't stop companies from emitting gases but I can stop myself from littering, I can walk to school, stop using plastic bags for example, the simplest thing to do. So, we should teach students what to do since young age and then go to the up levels" (PT3, personal interview, December 12, 2020). Moreover, PT3 identifies a gap at the level of governmental action plan in regards to environmental issues, in this regard PT3 voices "the stakeholders of this awareness of climate change are parents, teachers because children spend most of their time with their teachers and parents, and hence shape the child's minds. And the concept of climate change is not one day thing it is being environmentally friendly is a habit it is something you learn. And also, to make it possible, and accessible and we should have a government that actually acknowledges such things. We don't have proper recycling bins. Even if you teach your child to recycle in specific bins they don't even have the appropriate exposure to that. And this becomes too much for a parent and teacher" (PT3, personal interview, December 12, 2020). PT4 identified government and ministry of education as responsible for the integration of the climate change topic and awareness in curriculum and calls for interdisciplinary approach to teaching, in PT4's articulation "It could be integrated in any subject. It could be integrated in language subject. We can give them text that includes this kind of information in this way we can help children become more aware of the topic", "Governments, ministry of education for pedagogical concerns, it should be integrated in the curriculum, there should be teacher training, it should be interdisciplinary and integrated in all subjects. Since not all parents are educated, maybe if we help parents too, yes" (PT4, personal interview, December 12, 2020).

Some interviewees also stressed on development of physical facilities, such as recycling bins, at schools for proper climate change education or outside school. In this regard PT3 said, "We don't have proper recycle bins. Even if you teach your child to recycle in specific bins they don't have the appropriate exposure." Another interviewee stated, "Teaching students to recycle having bins everywhere. In my school we had the solar panels for electricity. Having these stuff around students will help them be aware of the subject" (PT2, personal interview, December 11, 2020). So even with the education at school or university levels there is a need for development of school infrastructure. One interviewee, however, brought the issue of personal and civic responsibility. Instilling the individual and civic responsibility will help the future generation face the climate change related challenges in a more informed way.

Regarding the second category, *Prospective teachers' perception of the importance of climate change education*, participants showed significant level of awareness for a need to improve their climate change knowledge and awareness for professional development. PT2 voiced "I think humans ruin everything, so humans are definitely causing this. Nothing will have changed if it remained untouched" (PT2, personal interview, December 11, 2020). PT3 recognized the need for raising awareness even if the climate change is sustained "we shouldn't stop teaching them because if we do that then we basically normalizing the issue and we are basically avoiding the fact that we can prevent it. It's gonna come back" (PT3, personal interview, December 12, 2020). Moreover, PT3 also referred to the underrating of this issue "I feel like it's a very underrated topic at schools for example, because it is just a topic that is there. All you have to do is don't litter, don't pollute. I mean it is not emphasized in a way like we are in danger" (PT3, personal interview, December 12, 2020). On the other hand, PT4 referred to the "history repeats itself" concept in this matter "I think yes there should be ongoing teaching about these subjects because you know the mistakes from the past could be repeated."

Regarding the third category, *Prospective teachers' perception of the need of professional training to tackle climate change issues*, participants showed significant level of awareness for a need to improve their climate change knowledge and awareness for professional development. PT1's discussions in this regard "it is important for them to have some knowledge about it so that they could teach it to others", "I admit that I don't have enough knowledge about it. And I feel that if I had more knowledge about it, I would be able to not only understand it but even to inform others about it. And work on something knowledge is power in the end. Academically don't have enough content knowledge, but in terms of google and other places that have valid resources we can benefit from them" (PT1, personal interview, December 12, 2020). While PT2 sees the need to a workshop, "Yeah, preparation maybe. Few ways of teaching, a workshop maybe" (PT2, personal interview, December 11, 2020), PT3 admitted the need for more content and pedagogical content knowledge "I think I need more content knowledge and it is actually fun to know about it. And pedagogical knowledge yes especially for the theme of the environment itself. Yes, we do need. But on very broad level" (PT3, personal interview, December 12, 2020).

In conclusion, the interviewees showed a significant level of climate change awareness, which was evident throughout the interview. The interviewees could correctly define climate change related terms such as “climate change”, “global warming”, “climate change awareness”. Examples from local context or global were mentioned when it came to discuss the effect of observable effect of climate change for example “scarcity of rain”, “desertification”, “increased heat”, “increase in sea levels” and “weather in Canada”. All four interviewees acknowledged the anthropogenic nature of climate change, and factors contributing to it such as industrial activities, use of fossil fuels, deforestation, pollution, car exhaust. They referred to locally visible impacts of climate change such as temperature rise, and change in weather and season patterns.

The interviewees showed concerns regarding the climate change and its impact on humans and environment, and pinpointed to the importance of climate change knowledge amongst the students as a key to mitigate climate change mitigation. Hence, the interviewees pinpointed the importance of climate change awareness, even if it becomes sustainable at a certain point. Accordingly, interviewees necessitated that awareness should start as early as possible K-12, however it is important that teachers take into consideration that the climate change concept is presented in age specific manner. Different stakeholders such as government, NGOs, teachers, social workers, parents were identified by the interviewees, who were hold to be responsible to raise awareness. Moreover, the need of physical facilities within and outside schools such as proper recycle binds and infrastructure was identified to be important to teach students about climate change. Although the four interviewees showed significant level of climate change awareness through their discussions and articulations, yet they feel the need of further content knowledge regarding climate change, further pedagogical content knowledge to be able to teach with age specific teaching methodologies, further need of professional development for in-service teachers regarding climate change knowledge and climate change awareness.

4.3 Overall Summary

In the previous sections direct quotes of the interviewees were added to show the similarities and contrasts in their reasoning regarding certain interview questions. Direct quotes were also used to show the different examples the interviewees mentioned to show their knowledge of climate change, awareness, and importance of raising awareness of students. Below is a summary that answers the three research questions through cross-verifying the results obtained through quantitative and qualitative data analysis.

Findings for research question 1: what are the levels of scientific literacy of prospective teachers in private universities in Lebanon?

The quantitative data analysis indicated a scientific literacy mean score of approximately 12 (Table 6) with a highest mean score of 19 for Q25 and a lowest mean score of 4 for that of questions Q24 and 28 (Figure 1). None of the participants ranked “very good” scientific literacy level, and most ranked in “very low” criteria n= 14 (50 %). The highest overall scientific literacy mean score is to that of prospective teachers in fourth year is 0.47 and the lowest overall scientific literacy mean score is to that of prospective teachers in third year, which is 0.47 (Table 8).

Quantitative analysis also showed that participants’ lowest scientific literacy scores were associated with skills related to quantitative aptitude and scientific reasoning and a relatively high abilities in skill 3 *Evaluating the use and misuse of scientific information*. Which was also articulated during the interviews, when interviewees articulated various challenges in regards to identifying elements of scientific research design, interpreting data presented in various forms such as tables, graphs, and performing basic mathematical calculations such as frequencies, percentages and probabilities.

One-way ANOVA revealed that that there were no statistically significant differences among the levels of scientific literacy of prospective teachers at different years at university at $\alpha = .05$ significance level.

Findings for research question 2: what are the climate change awareness levels of prospective teachers in private universities in Lebanon?

The analysis of the quantitative data obtained from the ASCC questionnaire indicated that the mean score of prospective teachers is 2.987 (Table 14) which could be inferred that the participants possessed high climate change awareness. Along the same lines, the articulations of the four interviewees showed a significant level of climate change awareness. However, all four interviewees discussed the need of more content knowledge regarding climate change and pedagogical content knowledge to be able to appropriately teach it in the future.

Based on the quantitative analysis results (In Table 15), it could be inferred that there are no statistically significant differences among the levels of climate change awareness of prospective teachers regarding the 15 items of ASCC instrument. Furthermore, the one-way ANOVA revealed that there are no statistically significant differences in levels of climate change awareness between the four participant groups, $F(3, 56) = 0.499$, $p > .05$.

The interviewees showed high awareness of the anthropogenic nature of climate change. The participants referred to locally visible impacts of climate change from increase in temperature during summer, and very cold winter, suggests that Lebanon is already experiencing the impacts of climate change, which indicates the need of getting the students, future citizens, prepared with content knowledge and awareness on adaptive and mitigative measures towards climate change. The locally observed effects of climate change create a more engaging means of addressing climate change issues and mitigation measures that could be taken at local scale. Prospective teachers also articulated the need of integrating the climate change awareness in different subject.

Overall, it could be inferred that there are no statistically significant differences in levels of climate change awareness between the 4 participant groups at different years at university. However, sample size in general, and unequal sample size per group in particular, should be taken into consideration during data discussion. Similarly, qualitative results confirm that participants provided similar articulation and hence, being at different level at university did not affect the vocalization regarding the climate change awareness. Challenges that prospective teachers are facing is the lack of content knowledge about climate change.

Findings for research question 3: What relation exists, if any, between Lebanese prospective teachers' levels of scientific literacy and climate change awareness?

The analysis of the quantitative data using Pearson's product-moment correlation coefficient showed that with the Pearson correlation coefficient, $r= -.145 < .05$ (Table 18) between the levels of scientific literacy and climate change awareness, showed a weak negative correlation between these two variables. These findings were confirmed with the qualitative data analysis as participants articulated their difficulty in analyzing the TOSLS survey questions, unlike the ASCC questions where most participants could express the reasoning behind their answers.

Interestingly, all the four participants had difficulty in expressing the concepts related to climate change scientifically and using scientific terminology which could be attributed to their low level of scientific literacy.

The study does not show a significant correlation between the levels of scientific literacy and climate change awareness of prospective teachers. Although this could be attributed to the small sample size, yet this is an important finding in the understanding of the relationship between these two previously unstudied factors and this paper comes to fill a gap in literature.

Chapter V

Discussion and Conclusions

This chapter discusses the results of the study in conformity with the three research questions and their connections to the literature. The following headings guide this chapter: “Overview of the Study”, “Discussion”, “Conclusion”, “Limitations”, “Implications” and “Recommendations”.

5.1 Overview of the study

This study aimed to answer the following research questions:

a. What are the levels of scientific literacy of prospective teachers in private universities in Lebanon?

b. What are the levels of climate change awareness of prospective teachers in private universities in Lebanon?

c. What relation exists, if any, between Lebanese prospective teachers’ levels of scientific literacy and climate change awareness?

Thirty prospective science teachers participated in this study, of which 93 % were females and 7 % were males, highlighting that teacher education programs in Lebanon attract more females than males. This gender imbalance is of great concern, but beyond the scope of this research.

5.2 Discussion

5.2.1 Research question 1: what are the levels of scientific literacy of prospective teachers in private universities in Lebanon?

The first finding indicated that the participants had a mean score of scientific literacy of approximately 12 (Table 6). This mean score is low for a prospective teacher who will empower students with scientific literacy in the future. The highest mean score obtained was 19 and the lowest was 4 from a total of 28. Based on the results, 79% of the participants had a low level of scientific literacy (Table 7). Prospective teachers with low levels of scientific literacy cannot be counted on to cultivate scientifically literate students or teach the curriculum efficiently (Bacanak & Gokdere, 2009).

These results are in line with several studies reported in the literature (Bacanak & Gokdere, 2009; Karamustafaoglu et al., 2013; Ozdemir, 2010; Rubini et al., 2016; Yetisir & Kaptan, 2008), and highlight the need for more attempts or strategies, at the university level, to improve the scientific literacy levels of prospective teachers. For example, teacher education programs need to increase the number of science content courses and provide more opportunities for prospective science teachers to develop their pedagogical content knowledge. This could be achieved through redesigning the science education programs offered by Department of Education with the aim to prepare scientifically literate teachers who possess the required scientific knowledge and competencies. Courses also need to be offered that emphasize the nature of science (Abd-El- Khalick and Lederman, 2000; Al Sultan et al., 2018); the history of science; laboratory skills; and interactions among science, technology and society.

The second finding indicated that the lowest scientific literacy scores (Figure 3) were associated with skills related to quantitative aptitude and scientific reasoning. Skills related to quantitative aptitude include (1) creating graphs, skill 5 (mean score 10); (2) solving problems, skill 7 (mean score approximately 11); and (3) understanding and interpreting basic statistics, skill 8 (mean score approximately 7). The skill related to scientific reasoning includes (1) understanding essential elements of research design, skill 4 (mean score 9). In this regard, triangulation with semi-structured interview was critical to confirm the low levels of scientific literacy, and particularly the aforementioned skills when the interviewees articulated their weakness in identifying a valid scientific argument, the difficulty in understanding the essential components of research design, interpreting graphs and performing basic mathematical calculations.

According to OECD (2016), scientifically literate people engage in reasoned discourse about science and technology, which requires mastery of the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically (p. 13). Moreover, to be able to address issues related to science and technology in everyday life, three domains of skills were highlighted by OECD (2013). These are (1) providing explanation of natural phenomena and technology and its significance on society; (2) conducting inquiry based scientific investigation, through identifying a question that could be investigated through scientific inquiry, design and conduct the investigation and propose solution to the problem; and (3) evaluating and interpreting data and scientific evidence. The low levels of the aforementioned scientific literacy skills of prospective teachers in this study means that most participants do not have enough scientific knowledge and skills, the ability to think critically about science in different contexts (such as social, economic, political), and the ability to relate science to events of everyday life. Such a finding may be due to the fact that prospective teachers enter into teacher education programs from various high school backgrounds. Many students enter the teacher education programs after completing non-scientific tracks in their high schools. For example, after completing Humanities program of the Lebanese Baccalaureate or the French Baccalaureate or a Freshman Arts program.

The third finding indicated that the highest overall scientific literacy mean score is to that of prospective teachers in fourth year (0.47) and the lowest overall scientific literacy mean score (0.31) is to that of prospective teachers in third year (Table 8). Moreover, one-way ANOVA revealed that there were no statistically significant differences among the levels of scientific literacy of prospective teachers at different years at university at $\alpha = .05$ significance level. These findings suggest that the four participant groups (first year, second year, third year, and fourth year) showed different levels of scientific literacy which is also noticed through the varied standard deviations of the different groups (Table 9). These results contradict to those reported by Al Sultan et al. (2018), in the US context, as well as with those reported by Cavas et al. (2013) and Altun-Yilcin et al. (2011),in the Turkish context, who concluded that prospective teachers had a satisfactory level of scientific literacy. There are several possible explanations for the difference between the current study compared to others. In their study, Al Sultan et al. (2018), Cavas et al. (2013) and Altun-Yilcin et al. (2011) obtained higher levels of scientific literacy in fourth year university prospective teachers compared to first year. The researchers related this to the contribution of the teacher education program in improving students' scientific content knowledge and hence scientific literacy levels. Al Sultan et al. (2018) also related the high levels of scientific literacy of fourth year students to the importance of being exposed to courses such as science education, science content knowledge, and particularly the nature of science, which allowed year four participants to perform better when they took the scientific literacy test. This also explains the low levels of scientific literacy in this study as approximately 67% of the participants had not taken any science courses (Table 2). Moreover, Al Sultan et al. (2018) also associated the high levels of scientific literacy, of 63.3% of the participants, to positive previous experience in science at the high school level, unlike in the present study where many participants had pursued non-scientific tracks in their high schools. This explanation also comes in line with Chin (2005), who pointed out the impact of school science achievement level on student's scientific literacy level. Furthermore, the difference between the data obtained in this study and previous ones may also arise from diversity of courses that different teacher education programs offer.

The finding of this study and previous studies by Al Sultan et al. (2018), Cavas et al. (2013) and Altun-Yilcin et al. (2011), also contradict findings by Chin (2005) who showed that prospective teachers entering the education major have satisfactory levels of scientific literacy. Chin related his findings to the fact that teacher education programs in Taiwan had recruited more high school students from science-track than non-science track, which will positively affect their professional development.

The results obtained regarding the first research question contribute to the existing literature in a number of ways. The first contribution is through the use of a mixed methods approach, which according to Almeida (2018), not only helps in collecting richer data, but also in overcoming the limitations of each of the quantitative and qualitative methodologies, when conducted alone. Second, as mentioned in Chapter 1, there are few studies related to prospective teachers' scientific literacy levels, which have relied on quantitative analysis to measure the scientific literacy levels of prospective teachers (Altun-Yalcin et al., 2011; Bacanak & Gokdere, 2009; Cavas et al., 2013; Chin, 2005; Karamustafaoglu et al., 2013; Ozdemir, 2010). Hence the findings of the present study contribute to the knowledge gap. Third, these results contribute to developing evidence-based recommendations for policy and practice in teacher education programs. In this regard, Shelley (2009) emphasizes the idea that evidence is important, yet not enough to make instructional decisions. Prospective teachers should have high levels of scientific literacy and confidence in teaching science to ensure effective science teaching (Avery & Meyer, 2012). Fourth, these results contribute to the literature providing insight regarding the levels of scientific literacy of prospective teachers in the Lebanese context, inviting for possibilities of conducting cross-cultural studies in the future.

5.2.2 Research question 2: what are the levels of climate change awareness of prospective teachers in private universities in Lebanon?

The first finding based on descriptive analysis of the quantitative data obtained from the ASCC questionnaire indicated that the mean score of prospective teachers is 2.987 (Table 14). While this result suggests that the participants have a significant awareness of climate change, such a conclusion only through a descriptive analysis may have been misleading as the literature has revealed misconceptions and misunderstandings of the term climate change, as well as of its causes and consequences. Teachers and students hold misconceptions regarding climate change related concepts such as greenhouse effect, ozone layer, pollution. Some of these misconceptions include that global warming causes ozone layer depletion (Boyes and Stanisstreet, 1997; Cimer, et al., 2011; Dove, 1996; Groves and Pugh, 1999; Kerr & Walz, 2007; Papadimitriou, 2004), that a direct connection exists between greenhouse effect and ozone layer depletion (Khalid, 2003), and that climate change causes pollution (Papadimitriou, 2004). A study conducted by Oruonye (2011) showed that 18.2% of students in tertiary institutions in Jalingo Metropolis, Nigeria, had never heard about climate change, and 81.8% of students had heard about it. When participants from the latter group were interviewed, 89% didn’t show enough knowledge of climate change, its causes and effects, and possible mitigative and adaptive measures. Oruonye (2011) concluded that the participants had a low level of climate change awareness. Similar results were obtained by Adebayo et al. (2013) who concluded that 90% of the population of Adamawa state, Nigeria, confirmed to be aware of climate change, yet 70% of them did not know the causes of climate change.

Hence, in this research triangulation was important to verify the findings of the descriptive analysis. The analysis of the interviews was in line with the quantitative analysis which showed that the interviewees had a significant level of climate change awareness. Apart from defining climate change and related terms, the interviewees endorsed the view that current climate change and its various effects experienced (For example; desertification, change in sea level) are anthropogenic while two of the interviewees explicitly supported the view that the natural cause of the climate change should not be ruled out. The analysis of interviews also showed that the interviewees were referring to local or global climate change related events (for example; rise in sea level, very cold winter in Canada, very hot summer in Lebanon). According to Anderson (2012), referral to local and tangible aspects of climate change during teaching is important to raise awareness, which hopefully helps students to show pro-climate change behaviors and mitigation. Furthermore, the interviewees also showed concerns about climate change and acknowledged the importance of teaching climate change through various subjects at school, and that raising awareness should start from kindergarten and continue to the high school years using age-specific terminologies and resources.

The second finding, with an attempt to investigate whether being at different years at university effects climate change awareness, is based on a quantitative analysis and the results obtained in Table 15. No statistically significant differences were found among the levels of climate change awareness of prospective teachers regarding the 15 items of the ASCC instrument. Furthermore, one-way ANOVA revealed no statistically significant differences in levels of climate change awareness between the four participant groups, F (3, 56) = 0.499, $p > .05$. These findings were in line with a study conducted by Dal et al. (2015), in the Turkish context, who attributed the high levels of climate change awareness of third- and fourth-year prospective teachers to a common content, environmental education and global issues, in teacher education curricula, which is offered for all three education programs; science, elementary, and social studies education. Along with the same line, Hidge et al. (2017) also showed that Turkish prospective science teachers had a significant level of climate change awareness yet they had uncertain beliefs. Those who valued nature showed more initiatives and pro-climate change behavior than those who did not value nature.

Interestingly, although this research showed that climate change awareness of prospective teachers is significantly high, the interviewees felt the need to acquire content knowledge and pedagogical content knowledge to effectively teach this concept to students. This advocates for the need to review the existing teacher preparation programs and the approaches used in teaching climate change since previous studies have shown a positive relationship between the teachers' confidence in teaching climate change and students' confidence in their knowledge and learning process (Stevenson et al., 2016).

5.2.3 Research question 3: what relation exists, if any, between Lebanese prospective teachers' levels of scientific literacy and climate change awareness?

The relationship between the levels of scientific literacy and climate change awareness was examined by means of Pearson's product-moment correlation comparing scores from TOSLS with those of ASCC. The Pearson correlation coefficient, $r= -.145 < .05$ (Table 18) indicated a weak negative correlation between these two variables. A possible explanation for this could be due to the fact that 67% of participants had not taken any science education course. Moreover, participants' achievement and motivation levels in science in their high schools years could be other variables that may have had an impact. This hypothesis is open for future research.

The findings from quantitative analysis were confirmed with the qualitative data. The interviewees articulated their difficulty in analyzing the TOSLS survey questions, unlike the ASCC questions where most participants could express the reasoning behind their answers. Interestingly, all the four interviewees had difficulties in expressing the concepts related to climate change scientifically and using scientific terminology which could be attributed to their low levels of scientific literacy. Bissel (2011) claimed that the responsibility of teachers is not restricted to pass the knowledge of climate change, but also to be able to counterweight the harm of media, and empower students with climate change content knowledge, and awareness.

The closest study in terms of studying these two variables was the one reported by Saribas (2015), who found a weak positive correlation between prospective teachers' scientific literacy and all dimensions of environmental literacy. The present study contributes to the literature through suggesting a relationship between levels of scientific literacy and climate change awareness within a particular context. I agree with Saribas (2015) that in order to deal with today's ongoing environmental issues, citizens should have satisfactory knowledge about environmental, social, and political issues. For this reason, prospective teachers, who are responsible to prepare future generations at a critical stage of their development, also need to have this knowledge (Martins, 2011).

5.3 Limitations and Directions for Future Research

At the completion of this research, some limitations of the study could be identified. First, access to prospective teachers proved to be the greatest limitations to this study. Despite the fact that four months were provided for data collection, only 30 prospective teachers agreed to participate in this study. This was partly related to the fact that the data collection coincided with lockdowns as a result of the COVID-19 pandemic. Hence, the selection of prospective teachers who participated in this study was through convenience sampling. Generalizability of the results should be done with care; as cultural context could be an important factor to consider. Future studies need to be conducted which broaden the scope and encompass multiple universities from different regions, and that use probability sampling to recruit participants. Such studies could help to replicate the present study, through systematic sampling to study in depth, and ensure stronger generalization.

The findings of this research confronted to new research ideas worthy of further investigations. Questions arose, that were beyond the scope of this research, yet clamor for further studies. A number of recommendations can be made for future research. Studies are needed that target:

a. Exploring the impact of teacher education curricula on prospective teachers' levels of scientific literacy and climate change awareness as well as their teaching practices;
b. Exploring factors that may contribute to the different levels of scientific literacy and climate change awareness of prospective teachers;
c. Investigating the current status of climate change education in Lebanon through classroom observations and interviews;
d. Exploring scientific literacy and climate change awareness levels of in-service science teachers at the primary, secondary and tertiary/ college levels;
e. Extending research of climate change awareness to beyond science teachers, as research is highlighting the need of interdisciplinary approach for teaching climate change (Bissel, 2011);
f. Exploring the relationship between the levels of climate change awareness and pro-environmental attitude. This is important, as a study by Kollmus and Agyean (2002) showed that there is no direct relationship between climate change knowledge and awareness and pro-environmental behavior; and
g. Studying the Lebanese context to other contexts through conducting cross-cultural comparative studies.

5.4 Conclusions

In order to cope with current environmental challenges, citizens need to have sufficient levels of scientific literacy and climate change awareness. Prospective teachers, as future in-service teachers, are entrusted the responsibility of empowering the future generations at early stages in their education. Hence, they need to have significant levels of scientific literacy and climate change awareness. Prospective teachers at the end of their program should have high levels of scientific literacy and self-efficacy in teaching science, as these could affect their teaching in the future (Al Sultan et al., 2018).

This study was the first attempt to explore the levels of scientific literacy and climate change awareness of Lebanese prospective teachers as well as the relationship between them. A weak negative correlation between these two variables was found.

The findings of this study clearly showed that prospective teachers participating in this study had low levels of scientific literacy. Moreover, no statistically significant differences were found among the levels of scientific literacy of prospective teachers at different years at university. The literature review showed the importance of scientific literacy as one of the main goals of science education to foster scientifically literate students. Obviously, there should be more effort in this regard to prepare future science teachers who are well trained and have adequate levels of scientific literacy, otherwise they cannot be expected to be able to develop scientifically literate future citizens.

Prospective teachers showed a significant level of climate change awareness. Moreover, no statistically significant differences were found in levels of climate change awareness between the participant groups at different years at university. Prospective teachers are aware of the effects of climate change, although they feel limited in their scientific and pedagogical content knowledge related to climate change. A number of participants in this study viewed the importance of teaching climate change and mitigation methods and agreed that it should be part of K-12 education.

5.5 Recommendations for Policy and Practice

In light of the findings of this study, the following recommendations for policy and practice are made:

- Faculty in Teacher Education programs are encouraged to foster scientific literacy and climate change awareness of prospective teachers. Science education programs need to emphasize these dimensions and prospective teachers at different years in their programs should have sufficient opportunities to develop their scientific literacy and climate change awareness levels through coursework in science content and pedagogical content knowledge.
- Prospective teachers need to engage in learning experiences that target developing their nature of science (NOS) understandings. Such learning experiences can have a positive impact on their levels of scientific literacy and climate change awareness.

5.5.1 Implications for science education policy and practice

1. Curriculum and resource developers should target developing resources and engaging learning materials that enhance learners' scientific literacy and climate change awareness levels. Such resources can be helpful for science teachers in their teaching.
2. Continuous professional development opportunities need to be provided for in-service science teachers so that they can revisit their pedagogical content knowledge related to scientific literacy and climate change awareness as well as methods for addressing them in their classrooms.

   Governmental and non-governmental organizations (NGOs) should encourage enhancing citizens' scientific literacy and climate change education. For example, they can organize climate change awareness campaigns.

3. School science curricula should reflect research-based best practices related to preparing scientifically literate students and fostering climate change awareness. Different stakeholders, including K-12 teachers, should be involved in developing these curricula.

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Appendix A

Test of Scientific Literacy Skills (TOSLS) Questionnaire

<u>Directions:</u> There are 28 multiple-choice questions. You will have about 35 minutes to work on the questions. Be sure to answer as many of the questions as you can in the time allotted.

Do NOT use a calculator. Thank you for your participation in this project!

1. Which of the following is a valid scientific argument?

a. Measurements of sea level on the Gulf Coast taken this year are lower than normal; the average monthly measurements were almost 0.1 cm lower than normal in some areas. These facts prove that sea level rise is not a problem.

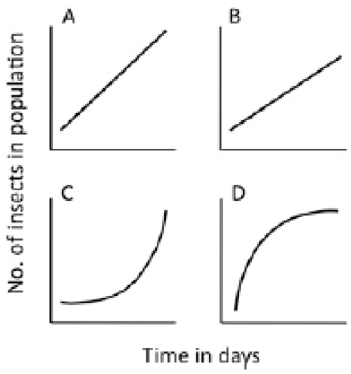
b. A strain of mice was genetically engineered to lack a certain gene, and the mice were unable to reproduce. Introduction of the gene back into the mutant mice restored their ability to reproduce. These facts indicate that the gene is essential for mouse reproduction.

c. A poll revealed that 34% of Americans believe that dinosaurs and early humans co-existed because fossil footprints of each species were found in the same location. This widespread belief is appropriate evidence to support the claim that humans did not evolve from ape ancestors.

d. This winter, the northeastern US received record amounts of snowfall, and the average monthly temperatures were more than 2°F lower than normal in some areas. These facts indicate that climate change is occurring.

2. While growing vegetables in your backyard, you noticed a particular kind of insect eating your plants. You took a rough count (see data below) of the insect population over time. Which graph shows the best representation of your data?

Time (days)	Insect Population (number)
2	7
4	16
8	60
10	123



3. A study about life expectancy was conducted using a random sample of 1,000 participants from the United States. In this sample, the average life expectancy was 80.1 years for females and 74.9 years for males. What is one way that you can increase your certainty that women truly live longer than men in the United States' general population?

a. Subtract the average male life expectancy from the average female expectancy. If the value is positive, females live longer.

b. Conduct a statistical analysis to determine if females live significantly longer than males.

c. Graph the mean (average) life expectancy values of females and males and visually analyze the data.
d. There is no way to increase your certainty that there is a difference between sexes.

4. Which of the following research studies is **least likely** to contain a confounding factor (variable that provides an alternative explanation for results) in its design?
a. Researchers randomly assign participants to experimental and control groups. Females make up 35% of the experimental group and 75% of the control group.
b. To explore trends in the spiritual/religious beliefs of students attending U.S. universities, researchers survey a random selection of 500 freshmen at a small private university in the South.
c. To evaluate the effect of a new diet program, researchers compare weight loss between participants randomly assigned to treatment (diet) and control (no diet) groups, while controlling for average daily exercise and pre-diet weight.
d. Researchers tested the effectiveness of a new tree fertilizer on 10,000 saplings. Saplings in the control group (no fertilizer) were tested in the fall, whereas the treatment group (fertilizer) were tested the following spring.

5. Which of the following actions is a valid scientific course of action?
a. A government agency relies heavily on two industry-funded studies in declaring a chemical found in plastics safe for humans, while ignoring studies linking the chemical with adverse health effects.
b. Journalists give equal credibility to both sides of a scientific story, even though one side has been disproven by many experiments.
c. A government agency decides to alter public health messages about breast-feeding in response to pressure from a council of businesses involved in manufacturing infant formula.
d. Several research studies have found a new drug to be effective for treating the symptoms of autism; however, a government agency refuses to approve the drug until long term effects are known.

Background for question 6: The following graph appeared in a scientific article about the effects of pesticides on tadpoles in their natural environment.

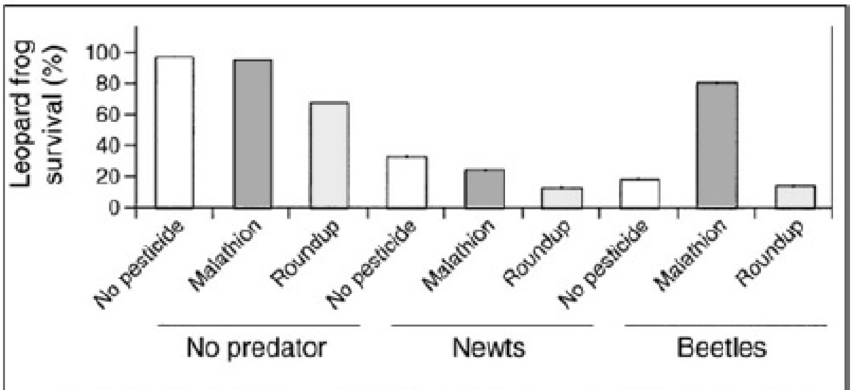
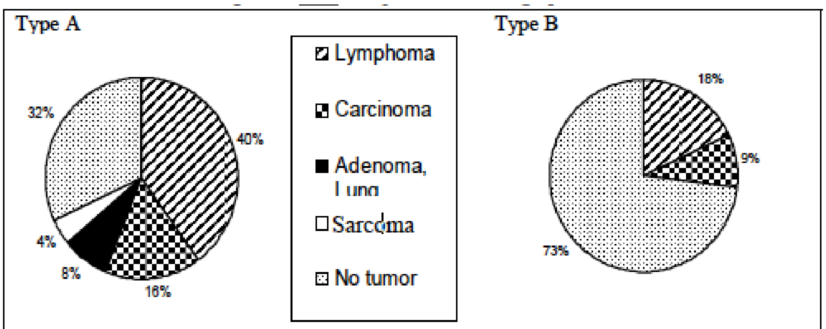


Fig. 2. Total survival of Leopard frog tadpoles living in ponds with 2 pesticides added (Malathion and Roundup) and 2 tadpole predators present (newts and beetles).

6. When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Which of the following is a plausible hypothesis to explain these results?

a. The Malathion killed the tadpoles, causing the beetles to be hungrier and eat more tadpoles.
b. The Malathion killed the tadpoles, so the beetles had more food and their population increased.
c. The Malathion killed the beetles, causing fewer tadpoles to be eaten.
d. The Malathion killed the beetles, causing the tadpole population to prey on each other.

7. Which of the following is the <u>best</u> interpretation of the graph below[2]?



Tumors found in type A and type B mice. Pie chart depicts relative incidence of tumors. Numbers outside each slice denote the percentage of specific tumor type.

a. Type "A" mice with Lymphoma were more common than type <u>"A"</u> mice with no tumors.
b. Type "B" mice were more likely to have tumors than type <u>"A"</u> mice.
c. Lymphoma was equally common among type <u>"A"</u> and type <u>"B"</u> mice.
d. Carcinoma was less common than Lymphoma only in type <u>"B"</u> mice.

8. Creators of the Shake Weight, a moving dumbbell, claim that their product can produce "incredible strength!" Which of the additional information below would provide the <u>strongest evidence</u> supporting the effectiveness of the Shake Weight for increasing muscle strength?

a. Survey data indicates that on average, users of the Shake Weight report working out with the product 6 days per week, whereas users of standard dumbbells report working out 3 days per week.
b. Compared to a resting state, users of the Shake Weight had a 300% increase in blood flow to their muscles when using the product.
c. Survey data indicates that users of the Shake Weight reported significantly greater muscle tone compared to users of standard dumbbells.
d. Compared to users of standard dumbbells, users of the Shake Weight were able to lift weights that were significantly heavier at the end of an 8-week trial.

9. Which of the following is **<u>not</u>** an example of an appropriate use of science?

a. A group of scientists who were asked to review grant proposals based their funding recommendations on the researcher's experience, project plans, and preliminary data from the research proposals submitted.
b. Scientists are selected to help conduct a government-sponsored research study on global climate change based on their political beliefs.
c. The Fish & Wildlife Service reviews its list of protected and endangered species in response to new research findings.

d. The Senate stops funding a widely used sex-education program after studies show limited effectiveness of the program

Background for question 10: Your interest is piqued by a story about human pheromones on the news.
A Google search leads you to the following website:

10. For this website (Eros Foundation), which of the following characteristics is **<u>most important</u>** in your confidence that the resource is accurate or not.
a. The resource may not be accurate, because appropriate references are not provided.
b. The resource may not be accurate, because the purpose of the site is to advertise a product.
c. The resource is likely accurate, because appropriate references are provided.
d. The resource is likely accurate, because the website's author is reputable.

Background for questions 11 – 14: Use the excerpt below (modified from a recent news report on MSNBC.com) for the next few questions.

"A recent study, following more than 2,500 New Yorkers for 9+ years, found that people who drank diet soda every day had a 61% higher risk of vascular events, including stroke and heart attack, compared to those who avoided diet drinks. For this study, Hannah Gardner's research team randomly surveyed 2,564 New Yorkers about their eating behaviors, exercise habits, as well as cigarette and alcohol consumption. Participants were also given physical check-ups, including blood pressure measurements and blood tests for cholesterol and other factors that might affect the risk for heart attack and stroke. The increased likelihood of vascular events remained even after Gardener and her colleagues accounted for risk factors, such as smoking, high blood pressure and high cholesterol levels. The researchers found no increased risk among people who drank regular soda."

11. The findings of this study suggest that consuming diet soda might lead to increased risk for heart attacks and strokes. From the statements below, identify additional evidence that supports this claim:

a. Findings from an epidemiological study suggest that NYC residents are 6.8 times more likely to die of vascular-related diseases compared to people living in other U.S. cities.
b. Results from an experimental study demonstrated that individuals randomly assigned to consume one diet soda each day were twice as likely to have a stroke compared to those assigned to drink one regular soda each day.
c. Animal studies suggest a link between vascular disease and consumption of caramel-containing products (ingredient that gives sodas their dark color).
d. Survey results indicate that people who drink one or more diet soda each day smoke more frequently than people who drink no diet soda, leading to increases in vascular events.

12. The excerpt above comes from what type of source of information?

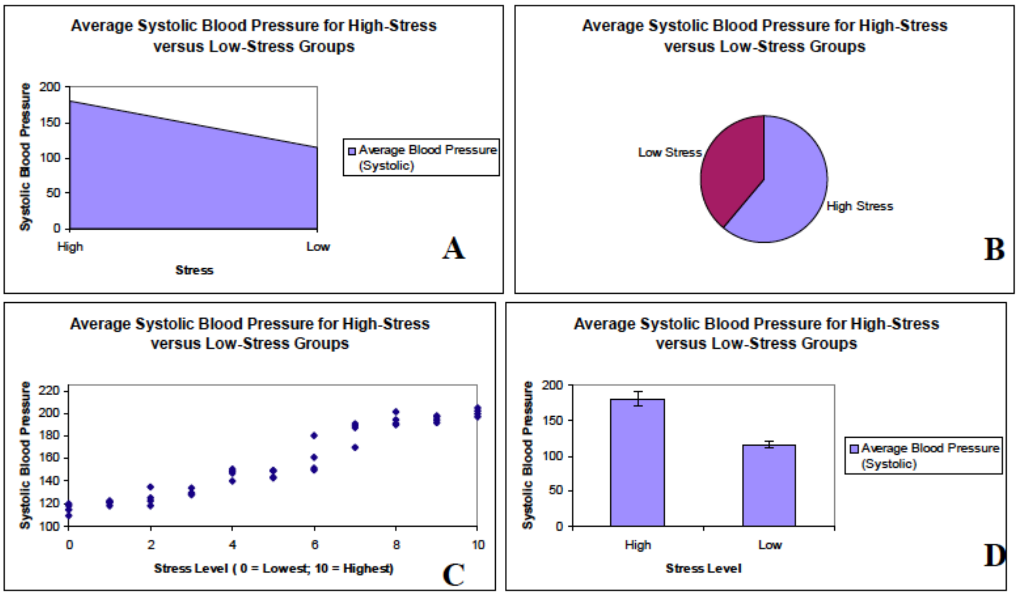
a. Primary (Research studies performed, written and then submitted for peer-review to a scientific journal.)
b. Secondary (Reviews of several research studies written up as a summary article with references that are submitted to a scientific journal.)
c. Tertiary (Media reports, encyclopedia entries or documents published by government agencies.)
d. None of the above

13. The lead researcher was quoted as saying, "I think diet soda drinkers need to stay tuned, but I don't think that anyone should change their behaviors quite yet." Why didn't she warn people to stop drinking diet soda right away?

a. The results should be replicated with a sample more representative of the U.S. population.
b. There may be significant confounds present (alternative explanations for the relationship between diet sodas and vascular disease).
c. Subjects were not randomly assigned to treatment and control groups.
d. All of the above

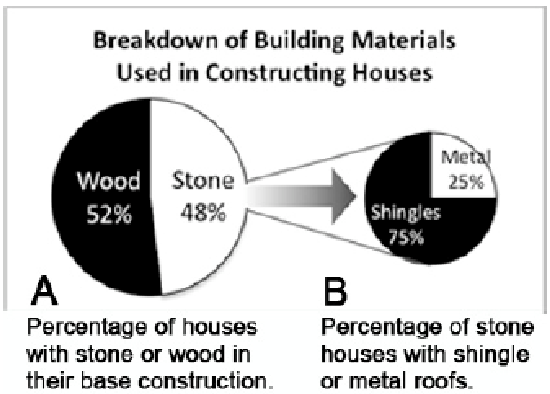
14. Which of the following attributes is not a strength of the study's research design?
a. Collecting data from a large sample size.
b. Randomly sampling NYC residents.
c. Randomly assigning participants to control and experimental groups.
d. All of the above.

15. Researchers found that chronically stressed individuals have significantly higher blood pressure compared to individuals with little stress. Which graph would be most appropriate for displaying the mean (average) blood pressure scores for high-stress and low-stress groups of people?



Background for question 16: Energy efficiency of houses depends on the construction materials used and how they are suited to different climates. Data was collected about the types of building materials used in house construction (results shown below). Stone houses are more energy efficient, but to determine if that efficiency depends on roof style, data was also collected on the percentage of stone houses that had either shingles or a metal roof.

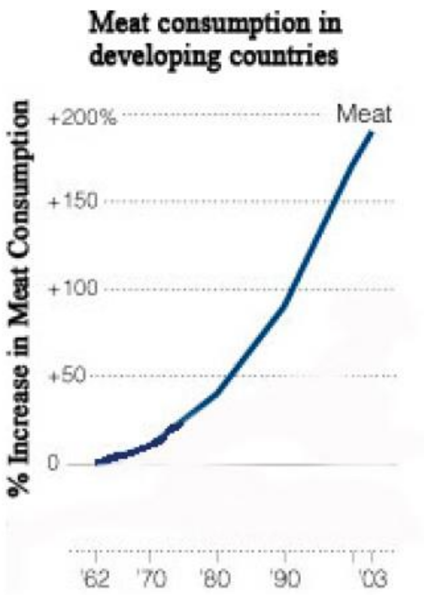
16. What proportion of houses were constructed of a stone base with a shingled roof?
a. 25%
b. 36%
c. 48%
d. Cannot be calculated without knowing the original number of survey participants.



17. The **<u>most important</u>** factor influencing you to categorize a research article as trustworthy science is:
a. the presence of data or graphs
b. the article was evaluated by unbiased third-party experts
c. the reputation of the researchers
d. the publisher of the article

18. Which of the following is the most accurate conclusion you can make from the data in this graph[3]?

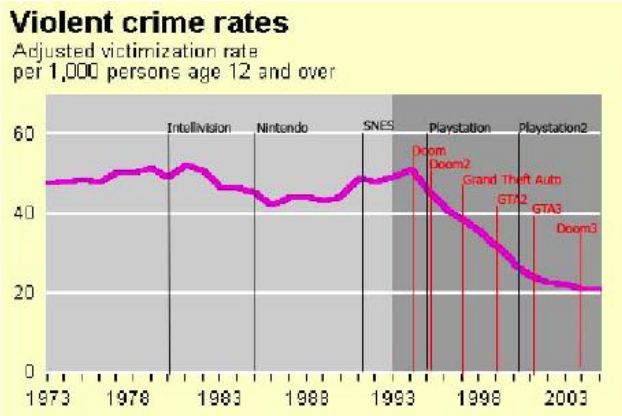
a. The largest increase in meat consumption has occurred in the past 20 years.
b. Meat consumption has increased at a constant rate over the past 40 years.
c. Meat consumption doubles in developing countries every 20 years.
d. Meat consumption increases by 50% every 10 years.



19. Two studies estimate the mean caffeine content of an energy drink. Each study uses the same test on a random sample of the energy drink. Study 1 uses 25 bottles, and study 2 uses 100 bottles. Which statement is true?
a. The estimate of the actual mean caffeine content from each study will be <u>equally uncertain</u>.
b. The uncertainty in the estimate of the actual mean caffeine content will be <u>smaller</u> in study 1 than in study 2.
c. The uncertainty in the estimate of the actual mean caffeine content will be <u>larger</u> in study 1 than in study 2.
d. None of the above

20. A hurricane wiped out 40% of the wild rats in a coastal city. Then, a disease spread through stagnant water killing 20% of the rats that survived the hurricane. What percentage of the original population of rats is left after these 2 events?
a. 40%
b. 48%
c. 60%
d. Cannot be calculated without knowing the original number of rats.

<u>Background for question 21:</u> A videogame enthusiast argued that playing violent video games (e.g., Doom, Grand Theft Auto) does not cause increases in violent crimes as critics often claim. To support his argument, he presents the graph below. He points out that the rate of violent crimes has decreased dramatically, beginning around the time the first “moderately violent” video game, Doom, was introduced.



21. Considering the information presented in this graph, what is the most critical flaw in the blogger’s argument?
a. Violent crime rates appear to increase slightly after the introduction of the Intellivision and SNES game systems.
b. The graph does not show violent crime rates for children under the age of 12, so results are biased.
c. The decreasing trend in violent crime rates may be caused by something other than violent video games.
d. The graph only shows data up to 2003. More current data are needed.

22. Your doctor prescribed you a drug that is brand new. The drug has some significant side effects, so you do some research to determine the effectiveness of the new drug compared to similar drugs on the market. Which of the following sources would provide the most accurate information?
a. the drug manufacturer’s pamphlet/website
b. a special feature about the drug on the nightly news
c. a research study conducted by outside researchers
d. information from a trusted friend who has been taking the drug for six months

23. A gene test shows promising results in providing early detection for colon cancer. However, 5% of all test results are falsely positive; that is, results indicate that cancer is present when the patient is, in fact, cancer-free. Given this false positive rate, how many people out of 10,000 would have a false positive result and be alarmed unnecessarily?
a. 5
b. 35
c. 50
d. 500

24. Why do researchers use statistics to draw conclusions about their data?

a. Researchers usually collect data (information) about everyone/everything in the population.
b. The public is easily persuaded by numbers and statistics.
c. The true answers to researchers' questions can only be revealed through statistical analyses.
d. Researchers are making inferences about a population using estimates from a smaller sample.

25. A researcher hypothesizes that immunizations containing traces of mercury do not cause autism in children. Which of the following data provides the strongest test of this hypothesis?

a. a count of the number of children who were immunized and have autism.
b. yearly screening data on autism symptoms for immunized and non-immunized children from birth to age 12
c. mean (average) rate of autism for children born in the United States
d. mean (average) blood mercury concentration in children with autism

Background for Question 26: You've been doing research to help your grandmother understand two new drugs for osteoporosis. One publication, Eurasian Journal of Bone and Joint Medicine, contains articles with data only showing the effectiveness of one of these new drugs. A pharmaceutical company funded the Eurasian Journal of Bone and Joint Medicine production and most advertisements in the journal are for this company's products. In your searches, you find other articles that show the same drug has only limited effectiveness.

26. Pick the best answer that would help you decide about the credibility of the Eurasian Journal of Bone and Joint Medicine:

a. It is not a credible source of scientific research because there were advertisements within the journal.
b. It is a credible source of scientific research because the publication lists reviewers with appropriate credentials who evaluated the quality of the research articles prior to publication.
c. It is not a credible source of scientific research because only studies showing the effectiveness of the company's drugs were included in the journal.
d. It is a credible source of scientific research because the studies published in the journal were later replicated by other researchers.

27. Which of the following actions is a valid scientific course of action?

a. A scientific journal rejects a study because the results provide evidence against a widely accepted model.
b. The scientific journal, Science, retracts a published article after discovering that the researcher misrepresented the data.
c. A researcher distributes free samples of a new drug that she is developing to patients in need.
d. A senior scientist encourages his graduate student to publish a study containing ground-breaking findings that cannot be verified.

<u>Background for question 28:</u> Researchers interested in the relation between River Shrimp (Macrobrachium) abundance and pool site elevation, presented the data in the graph below. Interestingly, the researchers also noted that water pools tended to be shallower at higher elevations.

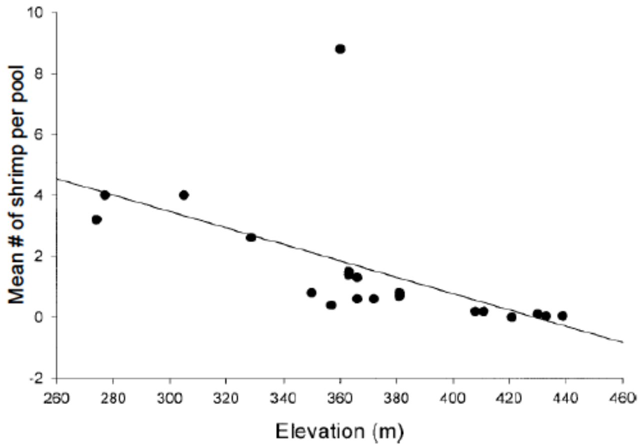


FIG. 3. Relationship between total abundance of *Macrobrachium* (1988–2002) and elevation in Quebrada Prieta.

28. Which of the following is a plausible hypothesis to explain the results presented in the graph?

a. There are more water pools at elevations above 340 meters because it rains more frequently in higher elevations.
b. River shrimp are more abundant in lower elevations because pools at these sites tend to be deeper.
c. This graph cannot be interpreted due to an outlying data point.
d. As elevation increases, shrimp abundance increases because they have fewer predators at higher elevations.

Appendix B

Test of Scientific Literacy Skills (TOSLS) Answer Key

Skill	Correct Reasoning	Question	Correct Answer
1 (3 Qs)	Identify a valid scientific argument (e.g., recognizing when scientific evidence supports a hypothesis)	1	B
		8	D
		11	B
2 (5Qs)	Conduct an effective literature search (e.g. Evaluate the validity of sources (e.g., websites, peer reviewed journals) and distinguish between types of sources)	10	B
		12	C
		17	B
		22	C
		26	C
3 (3Qs)	Evaluate the use and misuse of scientific information (e.g Recognize a valid scientific course of action, distinguish the appropriate use of science to make societal decisions)	5	D
		9	B
		27	B
4 (4 Qs)	Understand elements of research design and how they impact scientific findings/conclusions (e.g. identify strengths and weaknesses in research related to bias, sample size, randomization, experimental control)	4	C
		13	D
		14	C
		25	B
5 (1Q)	Make a graph	15	D
6 (4Qs)	Read and interpret graphical representations of data	2	C
		6	C
		7	A
		18	A
7 (3 Qs)	Solve problems using quantitative skills, including probability and statistics (e.g calculate means, probabilities, percentages, frequencies)	16	B
		20	B
		23	D
8 (3 Qs)	Understand and interpret basic statistics (e.g. interpret error bars, understand the need for statistics	3	B
		19	C
		24	D
9 (2 Qs)	Justify inferences, predictions, and conclusions based on quantitative data	21	C
		28	D

Appendix C

Awareness Scale for Climate Change Instrument

S/N	Item	SA	A	D	SD
1	Climate is dynamic and always changing through natural cycle.				
2	Climate change is a measurable increase in the average temperature of earth's atmosphere.				
3	Change in weather condition over an extended period of time is climate change.				
4	Climate change is characterized with high temperature.				
5	Climate change comes with a rise in sea level.				
6	Climate change is characterized by desertification.				
7	Most streams in hinterland are drying up as a result of climate change.				
8	There is an observed increase in sea level in the coastal areas.				
9	There is decrease in agricultural products in Lebanon.				
10	I have heard of climate change before.				
11	The rate of sunshine is higher now than before.				
12	The weather seems to be hotter nowadays.				
13	The atmospheric heat level is higher now than before.				
14	There is an increased rate of rainfall.				
15	Cases of flooding occur more nowadays.				

Appendix D

Interview Questions

The below questions are for a semi-structure interview. The questions will be used as the guiding framework for interviews. However, the researcher may choose to ask additional questions to follow up on the interviewee's responses as needed. The estimated interview time is 30 minutes.

I. Interview questions regarding the demographic data

1. Could you please tell me briefly about your educational background at school? At university?

II. Interview questions regarding scientific literacy.

1. Refer to the selected statements of the TOSLS and ask the interviewee to articulate their position regarding the statement with reasoning.

2. Is there anything else you can think of that you would like to share about scientific literacy?

III. Interview questions regarding climate change awareness

1. Please define the following terms: climate change, climate change awareness, global warming.

2. What are the differences between weather and climate?

3. At what level of education do you think climate change should be taught in the Lebanese education system?

4. Mention some aspects of climate change. Which one of these do you consider appropriate for the elementary school curriculum in Lebanon? Please list them.

5. In your opinion, which subjects should address climate change knowledge?

6. In your opinion, are there other subjects that should be added to what is currently taught to address issues of climate change in elementary curriculum. If yes, give a suggestion of a subject you consider most appropriate.

7. [Asking only if Question 6 is affirmative], explain how this can be done and which aspects of climate change should be specifically targeted.

8. In your opinion, should prospective teachers be offered professional training on how to tackle climate change issues in class?

9. Do you think the climate is changing? Why / Why not?

10. Which one is more believable, that climate is changing naturally or that humans are causing the climate to change? Why?

11. Is there anything that humans can do that would influence climate? If yes, what do you think humans can do?

12. Are there certain ideas related to climate change that you would not teach in the future? If yes, what are these? Why or why not?

13. The interaction of these three mechanisms: experience, attention and knowledge define climate change awareness. Do you agree? Why or why not?

14. In your opinion, what other mechanisms are missing to define awareness development of climate change?

15. Do you think that as prospective teacher you need more content knowledge related to climate change and more pedagogical content knowledge regarding climate change? Why or why not?

16. Do you agree that once climate change is sustained, it will no longer be relevant to develop climate change awareness in students?

17. Do you agree that climate change awareness should be maintained over time? Who are the stakeholders responsible?

Appendix E

Student Interview Scoring Rubric

Skill	Correct Reasoning	Question	Correct Answer
1 (3 Qs)	Evaluation of hypothesis with experiment; empirical test; draws conclusion that is based on strong evidence; provides reasoning for evaluating evidence; Evaluates the experimental design, recognizing confounds or need for random selection, or other independent variables	1	B
		8	D
		11	B
2 (5Qs)	Recognize sources of bias; quoting researcher does not indicate primary source; reviews are not primary; media reports are tertiary; peer review and importance of evaluation by 3rd party experts	10	B
		12	C
		17	B
		22	C
		26	C
3 (3Qs)	Recognize bias political or financial influences should not used to pressure findings, conclusions, reporting, or social decisions; decisions should be based on evidence; questionable ethics of publishing work that has not been verified; questionable ethics of distributing materials to bias participants; questionable ethics of rejecting studies based on controversy	5	D
		9	B
		27	B
4 (4 Qs)	No confounding factors (e.g., differences in sample size, sample selection, sample makeup); an explanation of how controls are used to mediate confounding factors; identifying strengths and weaknesses of experimental design (e.g., random assignment to control and treatment groups)	4	C
		13	D
		14	C
		25	B
5 (1Q)	Histogram is the best way to compare means	15	D
6 (4Qs)	Given data, be able to explain what the general shape of the graph would be (exponential/logorithmic vs linear); explain why the other shapes are not correct; interpret the graph and infer cause (e.g., pesticide killed the beetles which caused more tadpoles to be eaten); extract numerical information from graph and use that to make comparisons or conclusions; interpret shape of a graph to reach a conclusion	2	C
		6	C
		7	A
		18	A
7 (3 Qs)	Solve algebraic calculations accurately	16	B
		20	B

		23	D
8 (3 Qs)	Give measure of reliability such as use of statistical tests to define probability and certainty; how sample size effects certainty; Recognize that researchers use statistics to make inferences about a population using a sample of that population	3	B
		19	C
		24	D
9 (2 Qs)	Recognize or use reasoning to explain that correlation does not imply causation; using information from a graph to explain why they chose an answer that they did (e.g., the graph showed elevation and mean number of shrimp rather than having fewer predators)	21	C
		28	D

Appendix F

Frequency of correct answers, percentage and interpretation per question of TOSLS instrument

Table 7. Frequency of correct answers, percentage and interpretation per question of TOSLS instrument

Question Number	Frequency of Correct Answers	Percent Correct	Interpretation
Q1	14	50	low
Q2	10	36	very low
Q3	8	29	very low
Q4	13	46	low
Q5	15	54	low
Q6	16	57	enough
Q7	18	64	good
Q8	10	36	very low
Q9	15	54	low
Q10	11	39	very low
Q11	12	43	low
Q12	10	36	very low
Q13	8	29	very low
Q14	6	21	very low
Q15	10	36	very low
Q16	8	29	very low
Q17	16	57	enough
Q18	10	36	very low
Q19	10	36	very low
Q20	8	29	very low
Q21	14	50	low
Q22	16	57	enough
Q23	16	57	enough
Q24	4	14	very low
Q25	19	68	good
Q26	14	50	low
Q27	14	50	low
Q28	4	14	very low

Appendix G

Themes, categories, codes and meaning units of the data of the qualitative interviews (n = 4)

Theme 1: Understand Methods of inquiry that lead to scientific knowledge		
Category	**Code**	**Meaning unit**
Identify a valid scientific argument (1, 8, 11)	PT1 (2nd year)	Able to recognize what qualifies as scientific evidence. (Q1) Able to recognize when scientific evidence supports a hypothesis. (Q 8, Q11)
	PT2 (3rd year)	Difficulty in recognizing what qualifies as scientific evidence. (Q1) Able to recognize when scientific evidence supports a hypothesis. (Q 8, Q11)
	PT3 (4th year)	Difficulty in recognizing what qualifies as scientific evidence. (Q1, Q8) Able to recognize when scientific evidence supports a hypothesis. (Q11)
	PT4 (1st year)	Able to recognize what qualifies as scientific evidence. (Q1, Q11) Difficulty in recognizing what qualifies as scientific evidence. (Q8)
Evaluate the validity of sources (10, 12, 17, 22, 26)	PT1 (2nd year)	Inability to identify the accuracy of the resource. (Q10) Recognize the type of source. (Q12) Able to ensure objectivity of science (Q17, Q22) Recognizes the credibility of resource. (Q26)
	PT2 (3rd year)	Ability to identify the accuracy of the resource. (Q10) Recognize the type of source. (Q12) Able to ensure objectivity of science (Q17) Inability to ensure objectivity of science (Q22) Recognizes the credibility of resource. (Q26)
	PT3 (4th year)	Inability to identify the accuracy of the resource. (Q10) Inability to recognize the type of source. (Q12) Inability to ensure objectivity of science (Q17) Ability to ensure objectivity of science (Q22) Recognizes the credibility of resource. (Q26)
	PT4 (1st year)	Inability to identify the accuracy of the resource. (Q10) Inability to recognize the type of source. (Q12) Able to ensure objectivity of science (Q17) Inability to ensure objectivity of science (Q22)

Evaluate the use and misuse of scientific information (5, 9, 27)	PT1 (2nd year)	Recognizes a valid and ethical scientific source of action. (Q5, Q9, Q27)
	PT2 (3rd year)	Difficulty recognizing a valid and ethical scientific source of action. (Q5, Q9, Q27)
	PT3 (4th year)	Difficulty recognizing a valid and ethical scientific source of action. (Q5, Q27) Recognizes a valid and ethical scientific source of action. (Q9)
	PT4 (1st year)	Difficulty recognizing a valid and ethical scientific source of action. (Q9, Q27) Recognizes a valid and ethical scientific source of action. (Q5)
Understand elements of research design and how they impact scientific findings/conclusions (4,13,14)	PT1 (2nd year)	Recognizes the importance of random selection of participants. (Q4) Inability to identify elements of good research design. (Q13, Q14)
	PT2 (3rd year)	Recognizes the importance of random selection of participants. (Q4) Inability to identify elements of good research design. (Q13, Q14)
	PT3 (4th year)	Recognizes the importance of random selection of participants. (Q4) Inability to identify elements of good research design. (Q13, Q14)
	PT4 (1st year)	Inability to recognize the importance of random selection of participants. (Q4) Inability to identify elements of good research design. (Q14) Ability to identify elements of good research design. (Q13)
Theme 2: Organize, analyze, and interpret quantitative data and scientific information		
Create graphical representations of data (15)	PT1 (2nd year)	Able to identify the appropriate format for the graphical representation of data given particular type of data. (Q15)
	PT2 (3rd year)	Inability to identify the appropriate format for the graphical representation of data given particular type of data. (Q15)
	PT3 (4th year)	Able to identify the appropriate format for the graphical representation of data given particular type of data. (Q15)
	PT4 (1st year)	Able to identify the appropriate format for the graphical representation of data given particular type of data. (Q15)

Read and interpret graphical representations of data (2, 6, 7, 18)	PT1 (2nd year)	Difficulty to interpret data presented graphically to make a conclusion about study findings. (Q2, Q18) Ability to interpret data presented graphically to make a conclusion about study findings. (Q6, Q7)
	PT2 (3rd year)	Ability to interpret data presented graphically to make a conclusion about study findings. (Q2, Q18) Difficulty to interpret data presented graphically to make a conclusion about study findings. (Q6, Q7)
	PT3 (4th year)	Difficulty to interpret data presented graphically to make a conclusion about study findings. (Q2, Q7, Q18) Ability to interpret data presented graphically to make a conclusion about study findings. (Q6)
	PT4 (1st year)	Difficulty to interpret data presented graphically to make a conclusion about study findings. (Q2, Q18) Ability to interpret data presented graphically to make a conclusion about study findings. (Q6, Q7)
Solve problems using quantitative skills, including probability and statistics (16, 20, 23)	PT1 (2nd year)	Difficulty in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q16, Q20) Ability in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q23)
	PT2 (3rd year)	Difficulty in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q16, Q20, Q23)
	PT3 (4th year)	Difficulty in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q16, Q20) Ability in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q23)
	PT4 (1st year)	Difficulty in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q16, Q20) Ability in calculating probabilities, percentages, and frequencies to draw a conclusion. (Q23)
Understand and interpret basic statistics (3, 19, 24)	PT1	Ability to understand the need for statistics to quantify uncertainty in data. (Q3) Difficulty to understand the need for statistics to quantify uncertainty in data. (Q19, Q24)

	PT2	Ability to understand the need for statistics to quantify uncertainty in data. (Q3) Difficulty to understand the need for statistics to quantify uncertainty in data. (Q19, Q24)
	PT3	Difficulty to understand the need for statistics to quantify uncertainty in data. (Q3, 19, Q24)
	PT4	Ability to understand the need for statistics to quantify uncertainty in data. (Q3) Difficulty to understand the need for statistics to quantify uncertainty in data. (Q19, Q24)
Justify inferences, predictions, and conclusions based on quantitative data (21, 25, 28)	PT1	Difficulty interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q21) Ability interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q25, Q28)
	PT2	Difficulty interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q25, Q28) Ability interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q21)
	PT3	Ability interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q21, Q25) Difficulty interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q28)
	PT4	Ability interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q21, Q25) Difficulty interpreting data and critique experimental designs to evaluate hypotheses and recognize flaws in arguments. (Q28)

Appendix G

Theme 1: The Knowledge of Climate Change		
Category	**Code**	**Meaning unit**
Defining climate change related terms	PT1 (2nd year)	Climate Change is the variation or change in the climate. Climate Change Awareness relates to a person who has enough knowledge. Global Warming is an extra heating of the planet due to the pollution. Weather vs. Climate: Weather is related to whether it is sunny or rainy while climate is more general related to seasons or not really sure regarding climate.
	PT2 (3rd year)	Climate change is the average change in temperature due to the environmental changes and nitrogen and CO_2. Raising climate change awareness through movies. Weather it's the temperature levels, climate is more general like humidity maybe.
	PT3 (4th year)	Climate change is basically the change in the weather over a very long period of time due to environmental changes that happen in our habitat or ecosystem. Climate change awareness, knowing that climate change happens because of humans Global warming is associated with heat in the atmosphere, due to pollution rates and emissions of carbon. Weather is daily thing, climate is the phases of the year.
	PT4 (1st year)	Climate change is the change in earth temperature it could be manifested in increased rainfall, increase or decrease in temperature. people should be more aware about the things that cause climate change. There should be awareness campaigns and the government must also help to increase this kind of awareness. Weather vs. Climate: Climate is something that is long lasting, weather is something like "What's the weather today? It's sunny, it's raining.
Knowledge of climate change	PT1 (2nd year)	Climate change observed through rise of sea and ocean levels, Lack of rain, desertification Climate is changing by natural phenomenon and by human behavior

		Everybody is responsible to mitigate climate change
	PT2 (3rd year)	Humans are responsible to worsen the climate change
	PT3 (4th year)	Humans are responsible to worsen the climate change
	PT4 (1st year)	Humans are responsible to worsen the climate change Factories, cars, cutting trees are all causing climate change
Climate Change Awareness	PT1 (2nd year)	The interaction of experience, attention and knowledge define climate change awareness To develop climate change awareness through encouraging and supporting new ideas Even after climate change is sustained, awareness should still be developed in students
	PT2 (3rd year)	Raising awareness is important Each individual should take little steps to mitigate climate change. Climate change awareness is not important if it is no more a problem. Climate change should be maintained over time and the stakeholders are NGOs, social workers and governments.
	PT3 (4th year)	An underrated topic at schools Climate change awareness should be maintained over time, even if the issue is sustained Stakeholders are teachers, parents, government
	PT4 (1st year)	Climate change awareness should be maintained over time, even if the issue is sustained Stakeholders are government, ministry of education
Theme 2: Prospective Teachers' perception of climate change importance and need of professional development		
Realizing the importance of climate change education	PT1 (2nd year)	teaching about climate change should start at a young age Age appropriate content. Teaching ways to mitigate climate change. Climate change presented in form of plays and movies. support climate change related issues by school's principals, teachers and staff should Could be taught in any course with differences in the extent covered depending on the grade level

	PT2 (3rd year)	Teaching about climate change should start at KG Teaching students, the 3Rs Teaching students of recycling and having recycling bin everywhere Any homeroom teacher for kids and science teachers for the elderly.
	PT3 (4th year)	Climate change should be taught from kindergarten to adulthood and not only theoretically but implemented in daily life. Climate change knowledge should be addressed across all subjects.
	PT4 (1st year)	Climate change should be taught at elementary level. Integration of climate change related issues in any subject. Teaching climate change in an interdisciplinary way
Realizing the need of professional training to tackle climate change issue	PT1 (2nd year)	Importance of getting professional training on how to tackle climate change issues. Importance of getting professional training to get content knowledge in regards to climate change.
	PT2 (3rd year)	Importance of getting professional training on how to tackle climate change issues. Incorporating climate change issues within the whole school context. Importance of getting professional training to get content knowledge in regards to climate change.
	PT3 (4th year)	Need of right resources. Importance of getting professional training to get content knowledge and pedagogical content knowledge
	PT4 (1st year)	Importance of getting professional training on how to tackle climate change issues. Importance of getting professional training to get pedagogical content knowledge