MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2024, 20(3), em2407
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/14279

Assessment of scientific literacy levels among secondary school students in Lebanon: Exploring gender-based differences

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Received 04 November 2023 ▪ Accepted 07 February 2024

Abstract

In recent years, educational reforms have made scientific literacy a major priority because of its increasing importance in today's dynamic world. Program for international student assessment 2015 evaluated scientific literacy from 72 countries, and Lebanon ranked 65th. Scientific literacy levels among Lebanese secondary school students and gender differences are unknown. This study fills this research gap. A total of 130 students from Lebanon's private secondary schools were involved in this research. Scientific literacy levels were assessed using an instrument developed by Gormally et al. (2012), who conceptualized nine science competencies contributing to scientific literacy including understanding research designs, creating and interpreting graphs, and solving quantitative problems. Welch's ANOVA and Mann-Whitney U tests were used to analyze the data. Lebanese secondary school students have very low scientific literacy levels, and no significant difference was observed between genders. We present recommendations for adding desired skills to the curriculum based on a review of the underlying factors.

Keywords: scientific literacy, scientific literacy skills, secondary school students, gender

INTRODUCTION

Developing a thriving informed, and innovative society depends on individuals who are equipped with scientific literacy and are scientifically literate (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021). Science and technology continue to advance rapidly, and information is more readily accessible than ever before. Thus, individuals need to develop their scientific and technological skills in school and beyond (Fernández et al., 2022; Haleem et al., 2022). It is evident that the importance of scientific literacy extends beyond academic contexts to everyday life, as well as globally (Holbrook & Rannikmae, 2009). As a result, scientific literacy research has gained popularity both globally and internationally (Firdaus et al., 2023).

Early on in this study, it is important to note the variation in interpretations of the term "literacy". The traditional concept of literacy focuses on the ability to read and write, while scientific literacy has a different focus (Laugksch, 2000; Norris & Phillips, 2003). Scientific literacy encompasses not just the ability to read and write in scientific contexts, but also the ability to master knowledge, knowledgeability, learning, and education in general (Laugksch, 2000; Norris & Phillips, 2003). The focus of this study was on Organization for Economic Co-operation and Development (OECD) (OECD, 2023a) definition of scientific literacy, which refers to students' ability to engage with science-related issues, as well as with science ideas, as reflective citizens. Scientific literacy entails understanding science and technology in a reasoned manner, which includes understanding phenomena scientifically, evaluating and designing scientific explorations, and interpreting data and evidence scientifically (OECD, 2023a). The overarching objective of this research was not only to assess scientific literacy levels by examining basic problem-solving skills, but also broader conceptual understanding, such as application of scientific concepts in a real-world scenario, and critical thinking about scientific information in light of the specified definition of scientific literacy. In order to align with contemporary educational objectives and the demands of a rapidly evolving scientific landscape, we aimed to capture a richer and more nuanced understanding of scientific literacy.

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Contribution to the literature

- This study addresses a gap in the existing literature by being the first, to the best of the researchers' knowledge and based on a thorough literature review, to investigate scientific literacy among secondary school students in Lebanon.
- As well as providing critical baseline data on the scientific literacy levels of Lebanese students in secondary schools, this study will contribute to the knowledge base in the area of scientific literacy. In the future, research and policy decisions can be formulated based on the data.
- Moreover, this study could contribute to the development of strategies to enhance scientific literacy among secondary school students. Science teachers can use the findings of this study to avoid gender bias when teaching science.

It is generally believed that scientific literacy consists of several components, including: the ability to distinguish between scientific contexts and those outside of them; an understanding of the parts of science and a general understanding of its application; the ability to apply science knowledge to problem solving; the knowledge of science and its relationship to culture; and the awareness of the benefits and negative impacts of science (Holbrook & Rannikmae, 2009). The literacy component of science took on a new dimension in the 19th century when it was referred to as the ability to understand, identify, interpret, create, and communicate knowledge through the use of written materials that adapt to different contexts (Schleicher, 2009).

An individual's scientific literacy is their knowledge of science and science-based technology, as well as their specific goals, processes, and outcomes (Holbrook & Rannikmae, 2009). As well as understanding scientific concepts and theories, science literacy includes knowledge of procedures and practices in scientific inquiry, as well as how science can be developed (OECD, 2016, 2023b). All aspects of science require scientific literacy, from the basics to making important decisions for oneself, family, and society (Jacobsen et al., 2014). It is essential for people who actively participate in a community to have this ability (Hahn et al., 2013), since scientific literacy refers to being able to apply scientific knowledge in everyday life situations.

The ability to explain scientific phenomena, analyze and design scientific experiments, as well as interpret data and findings are some of the skills required for scientific literacy (OECD, 2016). Having a high level of scientific literacy skills has many benefits (OECD, 2023b). It is essential that individuals possess scientific literacy skills to evaluate and make decisions based on their abilities, knowledge, and experiences (Ibrahim, 2000). Students can improve their learning outcomes accordingly by learning and processing information using high-level thinking, which will be remembered and processed for longer and with greater clarity than information processed through low-level thinking (Genc, 2014). Students' scientific literacy skills should be developed through learning activities. Such activities can enhance students' self-confidence and self-potential (Genc, 2014).

Role of Science Education & Scientific Literacy

More than a decade has passed since science education around the world has emphasized the development of scientific literacy to prepare future citizens (Bybee, 2008; BouJaoude, 2002; Gormally et al., 2012; Miller, 2006; Zembylas, 2002). Understanding causality and finding a solution to a problem can both be improved by scientific literacy (Blake, 2017). Still, incomprehension of scientific concepts can be a significant problem for many people (Blake, 2017). During a period when scientific literacy is interconnected to economic growth and is essential for searching for solutions to complex environmental and social problems, not only future scientists and engineers but also future citizens should be willing and able to tackle science-related dilemmas (OECD, 2016, p. 6).

The workforce requires scientifically literate people (Rodriguez et al., 2022), who understand the implications of scientific and technological development in the advancement of society (Anaeto et al., 2016; Naikoo et al., 2018).

Although scientific literacy remains the primary goal of science education in many countries, what scientific literacy comprises is still pondered. Since scientific literacy is a socially formulated concept that changes depending on context and time (Laugksch, 2000; Linder et al., 2007; Miller, 1998), there appears to be some agreement on the necessity to reexamine the concept of scientific literacy based on global perspectives as well as 21st century skills that citizens need.

As per OECD (2017), a scientifically literate person can engage in a thoughtful discussion about scientific concepts and issues related to science and technology, requiring the capability of explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting scientific data.

Fundamental scientific literacy competencies include interpreting natural phenomena, designing and evaluating research experiments, and interpreting data scientifically (Mukti et al., 2019). Besides knowledge of scientific concepts and theories, scientific literacy also refers to awareness of procedures and practices in scientific inquiries (Chiappetta et al., 1991; OECD, 2016). Despite the efforts made to foster scientific literacy through science education, difficulties around the connection of science education to daily life situations continue (Sharon & Baram-Tsabari, 2020). Research by Aikenhead (2006) suggests that most students do not apply scientific knowledge to their daily lives. Despite efforts to foster scientific literacy, Feinstein et al. (2013) are uncertain whether these efforts will impact people's understanding of science in daily life. Countries like Australia, China, and South Korea have dissimilar political, social, cultural, economic, and educational backgrounds yet "Western" science is highly valued (Baker & Taylor, 1995) and puts a lot of effort into science education to nurture scientifically literate citizens in a global society (Mun et al., 2015). Inadequate scientific literacy skills predispose people to misinterpret facts and findings of science (Mukti et al., 2019). Scientific reasoning assists in understanding causation and determining the solution to problems (Mukti et al., 2019).

To prepare students for the challenges of the 21st century in science and technology, science education should encourage them to think critically, make informed decisions, improve survival strategies, and adapt to live effectively in a global community (Ibe et al., 2016). A wide range of skills should be developed by students to be able to handle quantitative scientific data phenomena (National Research Council [NRC], 2003), in addition to applying basic quantitative concepts to everyday situations (Kutner et al., 2007). According to the national assessment of adult literacy, quantitative literacy for adults is the ability to identify and perform quantitative tasks in their daily lives, such as identifying and computing numbers embedded in printed materials, calculating a percentage at the restaurant, or calculating the amount of interest on a loan (Kutner et al., 2007).

Lebanese National Curriculum & Scientific Literacy

Located in the Middle East, Lebanon is an Arab country with a multicultural and pluralistic culture (Bahous & Nabhani, 2008). Although Arabic is the national language in the country, science is taught in English or French (Dani, 2009). Public and private schools in Lebanon are divided into three levels, nursery, elementary, secondary, and intermediate education. Elementary education covers grade 1-grade 6 (age six-12), intermediate education covers grade 7-grade 9 (age 12-15), and secondary education includes grade 10-grade 12 (age 15-18). The Ministry of Education is a central institution in the education system (National Center for Educational Research and Development, 1995). Private schools must address the national curriculum, however, they are not bound by the science textbooks recommended by the ministry. It is the Ministry of Education's responsibility to recruit graduates from public Lebanese universities to teach in public schools. However, private school teachers are graduates of private universities whose teacher preparation programs have more rigorous requirements for course content, foreign language proficiency, and internships than at the public Lebanese University (Jarrar et al., 1988).

The current Lebanese science curriculum is the result of reform in 1998 (National Center for Educational Research and Development, 1995). Curriculum elements include general objectives (goals), introductions, objectives, and instructional objectives. Up to grade 10, it covers common science content. During the 11th grade, students are given the option of choosing a humanities or science stream for secondary study. Grade 12 further breaks the science stream down into general science and life sciences. Within a stream, all courses are predetermined. Although all students take science, the number of sessions students take varies depending on their level and stream (Dani, 2009).

BouJaoude (2002) investigated scientific literacy themes within the Lebanese science curriculum and its effectiveness in preparing scientifically literate citizens. To develop a scientific literacy framework, he considered

(a) knowledge of science, investigation of science, the role of science in knowing, and the interaction between science, technology, and society (Chiapetta et al., 1993),

(b) using science to solve everyday problems, make everyday decisions, and enhance one's life and dealing with science-related moral and ethical issues (Hurd, 1998), and

(c) domains of curricular science (Koballa et al., 1997), and science as one way of knowing rather than the only way (Shapin, 1998).

In his analysis, BouJaoude (2002) concluded that the Lebanese curriculum focuses on aspect 1; science knowledge, aspect 2; science as an investigative approach, and aspect 4; science, technology, and society interactions, omitting aspect 3; science as knowledge (BouJaoude, 2002). BouJaoude (2002) elaborated that it is important to prepare citizens who are capable of utilizing scientific knowledge effectively in their daily lives by emphasizing aspect 3; science as knowledge in the curriculum.

Scientific Literacy Levels of Students & Gender Differences

A science education should help students become more capable of facing challenges, making decisions, generating survival strategies, and adapting to the challenges of a multicultural society in the 21st century (Ibe et al., 2016). According to some research, male students are more likely to achieve cognitively and develop skills when compared to their female counterparts (Ige & Arowolo, 2003; Madu, 2004). It is important to provide equal opportunities to all students regardless of their gender for improving their performance in scientific literacy (Ibe, 2013).

We present previous research regarding scientific literacy levels among students of different countries based on their age/grade level and gender. To the best of the researchers' knowledge and based on a thorough literature review, a significant research gap exists in the Lebanese context. Julien and Barker (2009) conducted a study exploring the ways secondary school students assess scientific information. The researchers found that students cannot conduct complicated searches and evaluate information critically. Instead of relying on the content of the information on the internet, students assessed its trustworthiness based on the location or source. Moreover, the researchers found that the process of searching for information is less important to students than the results of the search (Julien & Barker, 2009).

Mukti et al. (2019) found that the scientific literacy skills of senior high school students, from three public schools in Malang, were still at the "development stage". Female students scored higher in scientific literacy skills compared to male students. To empower students with scientific literacy skills. The authors suggest the need for innovative teaching strategies such as constructivist, contextual, inquiry-based, and problem-based learning.

An assessment of civic scientific literacy was carried out by Rundgren et al. (2012), especially on how individuals understand scientific concepts and terms presented in the media. A group of 13 to 16-year-old secondary school students along with university students in Taiwan participated in the study. According to the authors, 16-year-old students scored the highest on average, probably because they were preparing for a nationwide test. Earth and space science was found to be the most successful area of study for these students. In contrast, Chih-Yang et al. (2012) observed that secondary school students in Taiwan have only above-average scientific literacy, while possessing greater knowledge of science ethics than application knowledge. As a result of this study, it was also found that girls pay more attention to scientific ethics, whereas boys pay more attention to scientific applications.

In the Korean context, Mun et al. (2015) addressed four dimensions, in particular:

(a) habits of the mind,

(b) character and values,

(c) science as a human endeavor, and

(d) metacognition and self-direction.

According to the study, secondary school students, in the last year, scored highest in "science as a human endeavor" and lowest in "metacognition and self-direction". There were also gender differences in the study; girls achieved higher scores in the "characters and values" and "science as a human endeavor" dimensions; boys did better in the "habits of mind" and "metacognition and self-direction" dimensions.

In a study by Ghazvini and Khajehpour (2011), female students performed better in literary lessons because they were better at controlling their attitudes, motivations, time management, anxieties, and self-testing strategies. On the other hand, male students are better at concentration, information processing, and strategy selection, which allows them to achieve higher math scores (Ghazvini & Khajehpour, 2011). The findings of other research have shown that male students perform better than female students in cognitive ability and skill enhancement tasks (Ige & Arowolo, 2003; Madu, 2004). To enhance students' scientific literacy, equal opportunities must be provided to all students, regardless of their gender (Ibe, 2013). In light of this exposure, the second purpose of this study is to analyze gender differences in scientific literacy levels.

Downing et al. (2008) highlighted various features that distinguish masculinity from femininity when determining gender. An important characteristic is the sex assignment, which identifies men and women. Men and women differ in their psychological characteristics according to their intelligence, attention span, interests, talents, motivation, maturity, and readiness. Learning activities and social activities of students will certainly differ due to gender differences (Downing et al., 2008). It has been recognized that gender differences exist in a variety of cognitive areas, including metacognition (Liliana & Lavinia, 2011) and critical thinking (Rodzalan & Saat, 2015).

Objectives of the Study

Lebanon participated in OECD's Program for International Student Assessment (PISA) in 2015 for the first time. Science and scientific literacy was the main focus of PISA 2006 and 2015 (OECD, 2023b). A total of 540,000 students from 72 countries took part in the PISA 2015 study (OECD, 2016). According to OECD's (2016) document, PISA's assessment of 15-year-olds focuses not only on reproducing knowledge but also on applying it to new contexts. This approach emphasizes mastering processes, understanding concepts, and coping with a variety of circumstances (OECD, 2016, p. 11). Lebanon did not participate in PISA 2022. In general, the results of PISA 2022 show that there is a need to strengthen the role of education in empowering young people to succeed and ensuring merit-based equality of opportunity (OECD, 2023a). Between 2018 and 2022, and on average across 35 OECD countries, mean performance dropped by almost 15 score points in mathematics and 10 score points in reading but did not change significantly in science (OECD, 2023a).

With the knowledge and skills, they acquire through schooling, 15-year-old students were assessed on their scientific literacy through PISA 2015. Additionally, PISA provides prospective perspectives on schooling systems, instructional approaches, strategies, as well as background data about students, teachers, and schools (OECD, 2016). Compared to an average of 489 points in other countries, Lebanese 15-year-old boys scored 381 points while girls scored 386 points. Surrounding 72 countries participating in PISA 2015, Lebanon was ranked 58th (Gurria, 2016). In terms of scientific literacy, Lebanon's mean score was 107 points below that of the OECD (PISA, 2018, p. 10). As compared to the average of the OECD countries, Lebanon scored below proficiency level 2 on PISA (PISA, 2018, p. 71). It is of concern nowadays that Lebanese secondary school students have poor scientific literacy, as one of the skills of the 21st century. For students to be able to apply scientific knowledge to real-world challenges in science, several researchers (e.g., Choi et al., 2011; Mukti et al., 2019) emphasize that they must master scientific literacy skills.

There is a notable gap in the current literature regarding the levels of scientific literacy attained by secondary school students in Lebanon. In light of this, it is crucial to research the profile of Lebanese students' scientific literacy levels. It is therefore the first objective of this study to identify scientific literacy levels among Lebanese secondary school students. Specifically in the Lebanese context, little is known about gender differences in scientific literacy levels. Hence, the second objective of the study is to determine the scientific literacy levels of secondary school students based on their gender.

The following key research questions were addressed in this study:

Research question 1. What are the levels of scientific literacy among secondary school students in private schools in Lebanon?

Research question 2. Is there a statistically significant difference in scientific literacy levels among students in grades 10, 11, and 12?

Research question 3. Does the level of scientific literacy among secondary school students differ between males and females?

METHOD

Participants

Among the 130 participants in this study were 54 males and 76 females attending private secondary schools in Beirut and the Matn Area. The students were between 16 and 18 years old. Based on a random sampling method, 95 students were selected from grade 10, 18 from grade 11, and 17 from grade 12. A sample of students from different grades of their programs (Lebanese baccalaureate program, or high school program) was essential for determining whether they displayed statistically significant differences in their scientific literacy levels. The number of students participating in the study at each grade level is shown in **Table 1**.

Table 1. Distribution of participants by grade level

Grade level	Number of students	Gender		Percentage (%)
		Male	Female	
Grade 10	95	41	54	73.10
Grade 11	18	5	13	13.80
Grade 12	17	8	9	13.10
Total	130	54	76	100

Table 1 shows that the research sample included participants from grade 10, 11, and 12 levels and genders. However, group sizes were not evenly distributed due to practical constraints. The analysis and discussion sections have been revamped to address this imbalance.

Instrument Used

To determine the level of scientific literacy, the test of scientific literacy skills (TOSLS) was administered. TOSLS instrument was developed by Gormally et al. (2012), from the Georgia Institute of Technology, University of Georgia. It is available for open access to determine levels of scientific literacy and can be accessed using the link: https://www.lifescied.org/doi/suppl/10.1187/cbe.12-03-0026/suppl_file/combinedsupmats.pdf

The translation of the instrument was deemed unnecessary due to the English proficiency of Lebanese students. All survey participants understood and responded accurately to the survey items using the English language. By doing so, we aimed to preserve the integrity of the original instrument and to minimize potential linguistic nuances. By using the original English form of the survey questionnaire, the survey questions are consistent and fidelity to their intended meaning can be ensured, contributing to the validity of the data collected.

The concept of scientific literacy used to develop TOSLS is based on the following two definitions, as described by Gormally et al. (2012). Scientific literacy is described by PISA and project 2016 (American Association for the Advancement of Science [AAAS], 1993) as the ability to use scientific knowledge to infer conclusions and to make informed decisions about the world and the effects of anthropogenic activity (OECD, 2003). On the other hand, scientific literacy is defined by NRC (1996) as the ability to evaluate information and arguments about the science presented by scientists and the media based on evidence and data.

Through an extensive literature review, Gormally et al. (2012) classified scientific literacy skills into two major categories: Aspect 1–Developing a comprehensive understanding of the inquiry method that leads to scientific knowledge, which includes the following skills

(1) identifying a valid scientific argument,

(2) evaluating the validity of scientific arguments,

(3) evaluating the use and misuse of scientific information, and

(4) understanding elements of research design.

Aspect 2–Organizing, analyzing, and interpreting quantitative data and scientific information, which includes the following skills

(5) creating graphical representations of data,

(6) reading and interpreting graphical representations of data,

(7) solving problems using quantitative skills, including probability and statistics,

(8) understanding and interpreting basic statistics, and

(9) Justifying inferences, predictions, and conclusions based on quantitative data.

In this study, students' scientific literacy levels were assessed using TOSLS instrument. As a preferred instrument for assessing students' scientific literacy levels, TOSLS instrument has gained prominence in the academic landscape since 2012. TOSLS has been found to be both reliable and valid in numerous studies over the past decade. Several studies utilizing TOSLS include those conducted by Arfiati et al. (2019), Pratiwi et al. (2023), Propsom et al. (2023), and Segarra et al. (2018). Research contexts across the globe have embraced TOSLS, attesting to its utility and contribution to science literacy. Moreover, TOSLS instrument is composed of 28 multiple-choice questions that are centered on real-world concerns, such as assessing the reliability of scientific information on a website or the evidence to support the effectiveness of fitness products (Gormally et al., 2012). As Gormally et al. (2012) identified, unlike other instruments that measure individual skills, TOSLS is a useful instrument for measuring nine scientific literacy skills. Moreover, TOSLS assesses students' scientific literacy skills for critically evaluating and solving socio-scientific issues within and outside of science classes (Gormally et al., 2012), a primary objective of science education (AAAS, 1990, 2010; Bybee, 1997; DeBoer, 2000). Furthermore, TOSLS is based on scientific literacy, in line with a relatively recent document regarding the goals of science education; the OECD (2003).

Procedure

The study was conducted in December 2022. We contacted a number of schools in the Beirut and Matn Regions based on convenience. The researchers were informed that some schools have a policy prohibiting participation in research. Schools that participated expressed a willingness to participate when contacted. Considering the COVID-19 pandemic, principals were contacted via email. They were provided with a detailed explanation of the study's objectives and methodology. Principals later shared details of the study with parents of secondary school students, who consented to their children taking part in this research. It is noteworthy to share here that as a result of the COVID-19 pandemic, the schools were operating in an online mode during the data collection phase.

After parental consents, classroom advisers read the research objective and methodology (documents previously shared with principals) during the advisory period. We used a Google Form to facilitate survey accessibility regardless of participants' schedules. A link to the survey was shared by the advisors and the entire 45-minute session was supervised by them. In order to fill out the online survey, participants had to read and understand a paragraph that states they have read and understood their voluntary participation in a research study. Additionally, they were informed of the research and methodology and that they could withdraw from the study at any time. Following their agreement to participate, participants were required to complete the survey by clicking the approval button.

Participants were not allowed to use calculators, tablets, smartphones, or any information sources, including books and websites while filling out the questionnaire. For each of the 28 multiple-choice questions, students had to choose 1 correct answer from four possible options. One point was awarded if participants selected the correct answer. There were no points awarded for choosing distractors or incorrect answers. A maximum of 28 points can be achieved on TOSLS test.

Reliability & Validity

The research instrument's reliability was assessed using Cronbach's alpha. Cronbach's alpha coefficient for the measurement scale was 0.71, suggesting that the scale is acceptable. 10 students participated in a pilot study to see if there were any ambiguities, errors, or problems with the questions. In the pilot study, participants had no difficulty understanding the survey questions and navigating the method of answering them. The analysis revealed no significant issues, ensuring a smooth and error-free data collection in the following phase. In order to ensure that the final results accurately reflect those from the full-scale study, the data obtained from the pilot study were excluded from the main data analysis.

Data Analysis Methods

Analyzing, presenting, and organizing the numerical data from the questionnaires was done using statistical techniques. To analyze quantitative data, descriptive

Table 2. A description of all 9 scientific literacy skills outlined by Gormally et al. (2012)

Skill	Description	Measure by question #
Aspect 1–Understand methods of inquiry that lead to scientific knowledge		
1	Identify a valid scientific argument	1, 8, & 11
2	Evaluate the validity of sources	10, 12, 17, 22, & 26
3	Evaluate the use and misuse of scientific information	5, 9, & 27
4	Understand elements of research design & how they impact scientific findings/conclusions	4, 13, & 14
Aspect 2–Organize, analyze, & interpret quantitative data & scientific information		
5	Create graphical representations of data	15
6	Read and interpret graphical representations of data	2, 6, 7, & 18
7	Solve problems using quantitative skills, including probability and statistics	16, 20, & 23
8	Understand and interpret basic statistics	3, 19, & 24
9	Justify inferences, predictions based on quantitative data	21, 25, & 28

data

Table 3. A descriptive analysis of levels' scientific literacy scores of secondary school students (n=130) obtained from TOSLS instrument

Mean	Median	Mode	Standard deviation	Minimum	Maximum	Variance
10.65	10.00	9.00	4.50	3.00	23.00	20.29

statistics were used to determine the mode, mean, variance, maximum and minimum scores, ranges, and standard deviations, of the levels of scientific literacy and gender. Welch's ANOVA in inferential statistics was used to determine whether statistically significant differences exist between levels of scientific literacy among the three grades, and Mann-Whitney U test was used to determine whether gender differences existed.

In order to determine whether statistically significant differences exist between levels of scientific literacy among the three grades. Scientific literacy levels were calculated based on the formula given below by Arikunto (2005). **Table 2** shows a description of all nine scientific literacy skills outlined by Gormally et al. (2012). Percentage (%) of scientific literacy level can be computed, as follows: (Number of correct scores×100)/number of maximum scores. The levels of scientific literacy were further categorized using Arikunto's (2013) criteria score intervals, as follows: Very good (80%-100%), good (66%-79%), enough (56%-65%), low (40%-55%), and very low (30-39%).

To answer research question 1, descriptive and inferential analysis methods were used. For research question 2, Welch's ANOVA statistical analysis and Bonferroni contrast were used. Finally, to address research question 3, Mann-Whitney statistical analysis method was used to determine if scientific literacy levels differ with gender in the study population. There is further information elucidating the rationale for selecting a particular statistical test in the results section preceding the actual analysis itself.

RESULTS

Assessment of Students' Levels of Scientific Literacy

TOSLS was used to determine the scientific literacy levels of 130 Lebanese secondary school students (grade 10 to grade 12). To run the descriptive statistics the total number of correct answers of each participant was taken as raw data. A value of one was given to each correct answer out of 28. As a measure of central tendency, the mean, median, and mode were calculated. As a measure of data dispersion, standard deviation and variance were calculated. The obtained results are shown in **Table 3**.

The scientific literacy score levels of secondary school students were approximately 11 based on the descriptive analysis (**Table 3**). According to Arikunto's (2013) criteria, secondary school students have a very low scientific literacy level. The mean of approximately 11.00 was slightly higher than median of 10.00 indicating that distribution is positively skewed (skewed to the right).

The median of 10.00 indicated that the data were symmetrical, and half of the data obtained were lower than 10.00 and the other half of the data were more than 10.00. The most frequent data was indicated by the mode of 9.00. The descriptive statistics also revealed that the lowest scientific literacy score obtained from TOSLS was 3.00, and the highest was 23.00 out of 28. A standard deviation (SD) of 4.50 reflected the dispersion of the distribution of the scientific literacy scores 99.99% of scientific literacy level scores are within 4.50 SDs around the mean. A variance of 20.29 indicates the average of the squared distances from each scientific literacy score to the mean of approximately 11.00.

To understand how each scientific literacy level score compares to other scores. The percentiles were calculated and shown in **Table 4**.

Table 4 shows that 90.00% of participants out of 130 have a scientific literacy level of more than or equal to five. The first quartile or the 25.00% of students' scientific literacy was below or equal to eight. The second quartile or 50.00%, represents the average, where half of scientific literacy scores were below 10 and half were above 10 (this is confirmed by the median in **Table 3**). The third

Table 4. Percentile distribution analysis for scientific literacy levels

Percentile	Scientific literacy level
P 10	5.00
P 25	8.00
P 50	10.00
P 75	13.00
P 90	17.00
P 99	21.71

Table 5. Distribution analysis of scientific literacy levels: Frequency (n) & percentage (%)

Point category	Frequency (n)	Percentage (%)
0-5	15	11.54
5-8	29	22.30
8-10	28	21.54
10-13	28	21.54
13-17	18	13.85
21 & more	12	9.23
Total	130	100

quartile or 75.00%, showed that 35.00% of participants had more than or equal to 13 at the scientific literacy level. 1.00% of the participants received more than or equal to 17 scientific literacy scores. And only 1.00% had a scientific literacy level of 21.71.

To provide an overview of the distribution of the scientific literacy levels, **Table 5** was constructed displaying frequency and percentage of each percentile.

Table 5 showed that 15 students received a scientific literacy level between zero-five (11.54%), and 12 students received a scientific literacy level of more than 21 (9.23%). Overall, secondary school students (n=130) performed differently on TOSLS questions. Thus, to determine the scientific literacy levels of secondary students, percentages were calculated, analyzed, and compared with Arikunto's (2013) interpretation of the scores.

Based on Arikunto's (2013) score interpretation data, **Table 6** shows n=1 participant achieved a "very good" level of scientific literacy (0.77%) with a score of 23, and n=39 of the participants achieved between 30-39, which indicates a "very low" scientific literacy level (30.00%), high number of participants n=44 (33.85%) scored below 30 indicating poor scientific literacy level. Still, since it is not included in Arikunto's (2013) criteria interpretation data, for the sake of this study "extremely low" naming was used to represent scientific literacy levels below 30 (33.85%). According to Arikunto's (2013) data score interpretation criteria, 84% of the participants ranked below the low criteria.

Table 7 indicated that the mean score of the grade 10 students' scientific literacy level was 11.00 out of 28, which is considered "very low" by Arikunto's (2013) score interpretation. The mean scientific literacy score for both genders' male and female in grade 10 is 10.00 (35.71%), which indicates a "very low" level of scientific

Table 6. Distribution of n=130 secondary school students grouped by total scores they obtained from TOSLS according to Arikunto's (2013) interpretation of scores

Score interval	Criteria	SL score out of 28	Frequency (n)	Percentage (%)
80-100	Very good	≤22	1	0.77
66-79	Good	18-21	9	6.92
56-65	Enough	16-17	11	8.46
40-55	Low	12-15	26	20.00
30-39	Very low	8-11	39	30.00
	Extremely low[1]	7≤	44	33.85
Total			130	100

Note. [1]The criterion "extremely low" does not appear in Arikunto's (2013) data on score interpretation but was used in this study as an explanation

Table 7. Mean & standard deviation (SD) of participants' scientific literacy levels on their grade level & gender

Grade level	Gender	Number of participants	Mean SL level/28	SD
Grade 10	Female	54	10.00	3.41
	Male	41	10.00	4.03
	Total	95	11.00	4.50
Grade 11	Female	13	13.00	4.83
	Male	5	14.00	7.95
	Total	18	13.00	5.68
Grade 12	Female	9	12.00	6.18
	Male	8	15.00	4.98
	Total	17	13.00	5.61

literacy. Moreover, the mean scientific literacy level of grade 11 students was 13.00 (39.29%). This indicates a "very low" level of scientific literacy. The mean score for the scientific literacy of grade 11 male participants was 14.00 (50.00%) and the mean score for grade 11 female participants was 13.00 (46.43%), which falls under the category of "low" scientific literacy level. Also, grade 12 students' scientific literacy level is 13.00 (46.43%), which is considered "low". There was a slight difference between male and female participants, 15.00 (53.57%) and 12.00 (42.86%), but both genders fall under the same category of "low".

In order to conduct a deeper analysis, participants were awarded one point for each correct answer to a question. Neither distractors nor incorrect answers were given points. Using this information, the average success rate was calculated for each skill and further analysis was carried out, as shown in **Table 8**.

With an average rate of 13.85% aspect 2, organize, analyze, interpret quantitative data and scientific information participants scored better than aspect I, Understanding methods of inquiry. However, in both cases, it indicates an inadequate scientific literacy level among participants. As an aside, the categorizations "aspect 1–Understanding scientific methods of inquiry" and "aspect 2–Organize, analyze, and interpret quantitative data and scientific information" were derived from Gormally et al. (2012).

Table 8. Participants' levels of scientific literacy based on two aspects of scientific literacy

Aspect of scientific literacy (Gormally et al., 2012)	Scientific literacy skills (Gormally et al., 2012)	Questions (Gormally et al., 2012)	Average score of each skill (%)	SD	Average score of each aspect (%)
1. Understand methods of inquiry	1	1, 8, & 11	15.38	0.99	10.19
	2	10, 12, 17, 22, & 26	1.54	1.21	
	3	5, 9, & 27	16.15	1.05	
	4	4, 13, & 14	7.70	0.86	
2. Organize, analyze, & interpret quantitative data & scientific information	5	15	36.15	0.48	13.85
	6	2, 6, 7, & 18	6.15	1.13	
	7	16, 20, & 23	13.08	0.10	
	8	3, 19, & 24	8.46	0.91	
	9	21, 25, & 28	5.38	0.86	

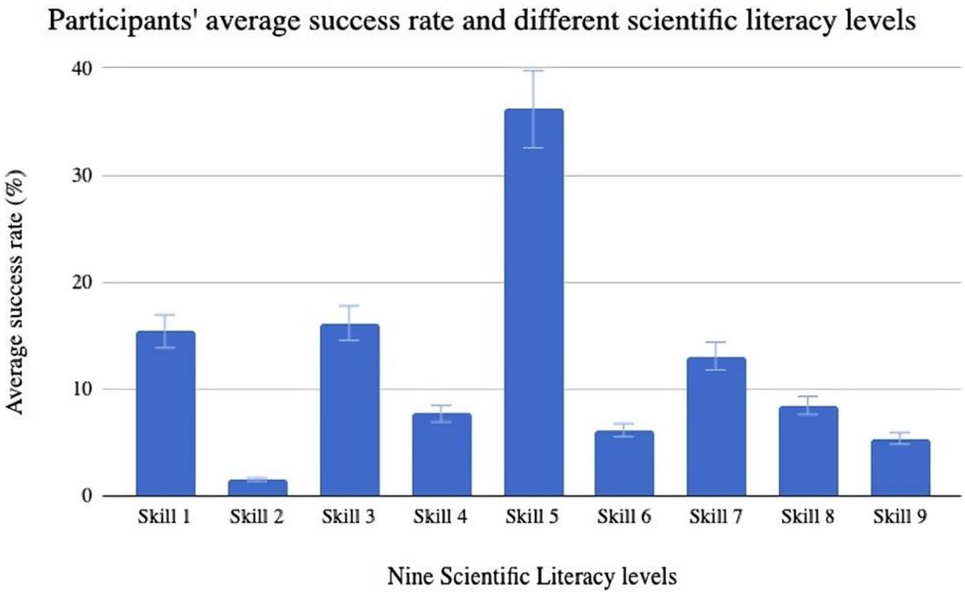

Figure 1. Average success rate of scientific literacy level & 28 TOSLS questions based on nine skills

To further analyze the data, a bar graph was drawn (**Figure 1**) highlighting the average success rate (%) of the responses for each of 28 TOSLS questions grouped by nine skills (see Gormally et al., 2012).

Among the skills, skill 1 recognizing a valid scientific argument, skill 3 evaluating how scientific data is used and misused, and skill 5 creating graphical representations of data had the highest average success rate. Although skill 5 had the highest average success rate (36.15%), it is important to note that this specific skill was assessed using only one question. The lowest mean score obtained was skill 2, which focuses on assessing sources' credibility.

To determine whether gender plays a role in excelling in a certain skill, average success rates were calculated by gender (**Figure 2**).

Having completed descriptive and inferential analysis, we now move on to statistical analysis. In order to assess the scientific literacy levels of the participants, a robust statistical analysis was used. Before proceeding with further analyses. Levene's test was used to test the assumption of homogeneity of variance in order to determine if there were statistically significant differences between the grades' scientific literacy levels. The significance level was set at 0.05. Using Levene's test, we tested the following hypotheses:

- **H_0.** The scientific literacy levels of different grades have equal population variance.
- **H_A.** The scientific literacy levels of different grades do not have equal population variance.

Table 9 summarizes the statistical data generated.

Using Levene's test for homogeneity of variance, the $F(2, 127)=8.18$ indicated that the null hypothesis, which states that the variances for the three grade levels are equal, should be rejected. This suggests that there is a significant difference between the variances among the three grade levels. In order to determine whether statistically significant differences exist between levels of scientific literacy among the three grades, Welch's ANOVA was used. Welch's ANOVA can accommodate unequal variances and unequal sample sizes among groups. The significance level was set at 0.05. Using Welch's ANOVA, we tested the following hypotheses:

- **H_0.** The mean scientific literacy level scores of different grade levels are equal.
- **H_A.** The mean scientific literacy level scores of different grade levels are not equal.

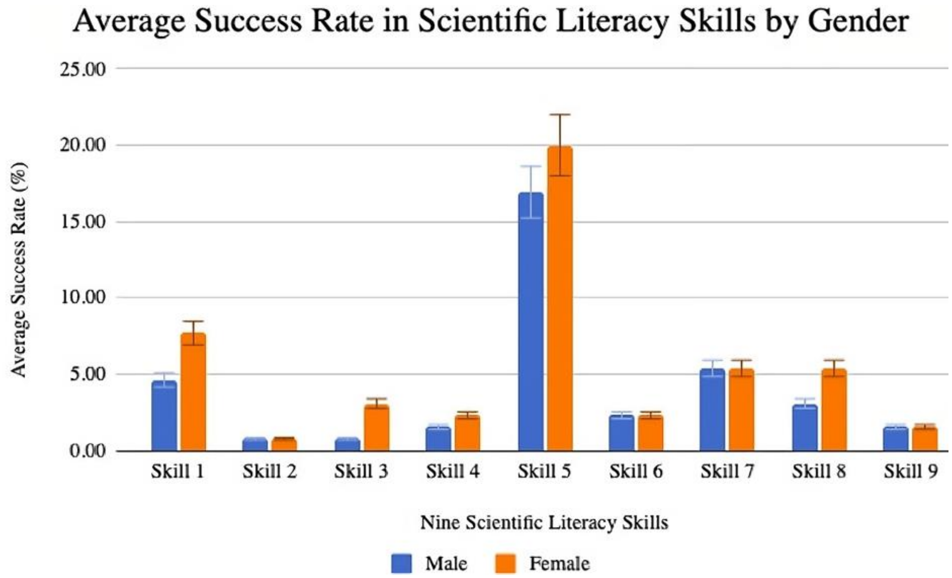

Figure 2. Average success rate for each of nine scientific literacy skills according to gender

Table 9. Results of Levene's equality of variance test based on 28 items from TOSLS instrument

SV	SS	df	MS	F	p-value	FC
BG	298.59	2.00	149.30	8.18	0.0005	3.07
WG	2,319.13	127.00	18.26			
Total	2,617.72	129.00				

Note. SV: Source of variation; BG: Between groups; WG: Within groups; & FC: F critical

Table 10. Welch's ANOVA test results

df_1	df_2	F statistics	p-value
2	25.22	5.40	0.01

Table 10 summarizes the statistical data generated.

Welch's ANOVA revealed that F (2, 25.22)=5.40, p<.05. Thus, the null hypothesis was rejected. The results suggested statistically significant differences between grade levels related to scientific literacy at α=.05 significance level. In order to identify which grades differed statistically from each other in terms of scientific literacy levels, a Bonferroni post hoc test was performed. Based on Bonferroni correction, 0.0167 represents the alpha level. A summary of the results is provided in Table 11.

Bonferroni post hoc test results indicated that grade 10 and grade 11, and grade 10 and grade 12 have significantly different scientific literacy levels.

At this stage of our research, we transitioned to conducting Mann-Whitney U statistical test to assess if there were statistically significant gender-based differences. Mann-Whitney U test was used to investigate potential differences between two genders in terms of scientific literacy levels. Due to the nature of the data, this non-parametric approach was chosen rather than a parametric one. Statistical comparisons between the different groups were thus assured of robustness and validity. The statistical data generated were tabulated in Table 12. We tested the following hypotheses:

Table 11. Bonferroni post-hoc test: Pairwise comparisons with significance levels

Groups	p-value	Significance
G10 vs. G11	0.001	Yes
G11 vs. G 12	0.973	No
G12 vs. G10	0.002	Yes

Table 12. Mann-Whitney test statistics (n=130)

	n	R	U
Male	54	3,623	1,966
Female	76	4,892	2,138

Note. Z-score -0.40 & p-value 0.69 at 5% significance level

H_0. There is no significant scientific literacy level difference between the two genders.

H_A. There is a significant scientific literacy level difference between the two genders.

Since p>.05 the results suggested that we fail to reject the null hypothesis. As a result, there was not enough statistical evidence to conclude that the two genders differ significantly in their levels of scientific literacy.

DISCUSSION

Science Literacy Levels of Secondary School Students in Lebanon

According to the findings of TOSLS test, the minimum score attained was three and the maximum score was 23 out of 28 points. The median score achieved in the test was 10.00; the mean was 10.65; and the standard deviation was 4.50 (Table 3). According to the results, 20.00% of the participants had low scientific literacy levels, 30.00% had "very low" scientific literacy levels, and 33.85% were below this latter criterion for this study, the term "extremely low" has been used (Table

6). Using the percentile distributions and frequency distributions of scientific literacy scores (**Table 4** and **Table 5**), it was determined that 20.00% of participants had a low scientific literacy level, and 64.00% had a very low to extremely low level (**Table 5**). Meanwhile, only 8.00% of the participants achieved a scientific literacy score of 18 or higher (out of 28). The data suggest that a significant percentage of participants were "very low" or "extremely low" in their level of scientific literacy. Based on the interpretation of scores by Arikunto (2013), the analysis of scientific literacy shows that proficiency levels are well below the established boundaries for very low. Hence, the criterion "extremely low" was used in this study. This highlights the challenges and opportunities for improvement in scientific literacy among the participants. A targeted educational strategy and effective interventions are imperative for enhancing science skills in the studied population in light of these findings.

These results were congruent across different contexts that assessed the scientific literacy levels of secondary school students in different countries. For example, Mukti et al. (2019) noted that senior high school students were still in the development stage during this period. According to Wahab et al. (2023), 62 out of 102 students had deficiencies in scientific literacy. A study by Adnan et al. (2021) found that South Sulawesi Junior High School biology students displayed poor scientific literacy skills. Other experiments that were conducted elsewhere corroborated similar findings, for example, Shahzadi and Nasreen (2020) conducted a survey of public schools in Lahore and found that there is a very low level of scientific literacy.

A more detailed breakdown of the skills levels of the participants was also achieved by using Gormally et al.'s (2012) TOSLS instrument, which measures nine skills related to major aspects of scientific literacy. Results of the descriptive analysis (**Table 7**) indicate participants' scientific literacy skills are weak (mean success rate of 10.19%) when it comes to organizing, analyzing, and interpreting quantitative data (aspect 2) when compared with understanding methods of inquiry (mean success rate of 13.85%; aspect 1). In addition, the descriptive analysis (**Table 7**) revealed that the highest recorded mean success rate of scientific literacy skill was 36.15%, which targeted participants' ability to create graphical representations of data (skill 5), suggesting a relatively low level of proficiency in scientific literacy. Now we will examine each skill individually, interpreting the results based on Arikunto's (2013) score interpretation, unless the skill is below "very low" criteria in which case "extremely low" wording was used.

Skill 1, which assesses a participant's ability to identify valid scientific arguments had an average success rate of 15.38% (**Table 7**) indicates that they are extremely poor in this area. This could be interpreted as participants misinterpreting the evidence or relying on poll results, public opinion, or limited data. Furthermore, they did not understand causation or correlation relationships.

With regard to skill 2, which focuses on evaluating sources' credibility, participants obtained the lowest average success rate 1.54% (**Table 7**), indicating "extremely low" proficiency. In many cases, participants believed that a website with links and references was reliable, rather than correctly evaluating a website's credibility. This is concerning since students and the wider public are most likely to obtain technical and scientific information from newspapers, the Internet, and magazines (Norris & Phillips, 2003; Rundgren et al., 2012), with the Internet being the most commonly used resource for students to conduct research (Julien & Barker, 2009). A similar problem was encountered when participants could not identify a fragment of an article as either a primary, secondary, or tertiary source of data. According to results, participants failed to comprehend media reports and discussions on science and failed to read simple science-related newspaper articles.

Skill 3, which measures the participants' ability to evaluate social uses and misuses of scientific information, had an average success rate of 16.15%, which is considered "extremely low". In order for scientific decisions to be based on sound reasoning, rigorous research, and ethical standards, rigorous research must be conducted. In the answers given by participants, weak scientific reasoning was evident, with the potential to prioritize business interests over scientific evidence, objectivity, ethics, and the public's well-being. This may lead to the perpetuation of inaccurate and misleading information, and scientific literature is not given sufficient credibility.

Skill 4, which tests the ability of participants to understand elements of research design and how they affect scientific findings and conclusions. About 8% of participants achieved a proficiency level classified as "extremely low". This indicated that participants underestimate the importance of control groups as an essential element of research. Participants also struggled to understand the significance of the choice of research sample and research group on the validity of the results. Most participants lack a general understanding of the elements of a good research design.

Skills 5 (creating graphical representations of data) and skill 6 (reading and interpreting graphical data) had "extremely low" proficiency levels, with an average success rate of 36.15% and 6.15%, respectively (**Table 8**). Based on these findings, participants lack graphical literacy and are not able to read and interpret charts and graphs and plot graphs based on the data.

With an approximate average success rate of 13.00% (**Table 8**), participants were unable to extract information from the graph when it came to problem-solving using quantitative skills, including probability and statistics (skill 7), which indicated that they lacked knowledge of research methods and research literacy. Also, participants had inadequate math skills, including basic calculations and probability knowledge.

In skill 8, participants were tested on their understanding and interpretation of basic statistics and their average success rate was 8.46%. In terms of scientific literacy, this skill is considered to be "extremely low". These findings showed that participants lacked knowledge of statistics, statistical literacy, scientific reasoning, and research methodology. In addition, participants were unaware of how sample size impacts generalizability and representativeness. It is important to interpret graphs and analyze experiment results statistically (Glazer, 2011; Samuels et al., 2016) in order to develop scientific literacy. According to Matthews (2012), poor arithmetic skills hinder students from developing scientific literacy.

An average success rate of 5.38% was achieved by participants in skill 9, which requires the ability to justify inferences, predictions, and conclusions based on quantitative data. Participants did not demonstrate sufficient ability to develop conclusions based on the graph. The findings of skill 9 may be compared to those of skill 6 the ability to read and interpret graphical representations of data, since skill 6 focuses on reading and interpreting data graphs. Participants seem to lack competencies in these areas.

Based on the detailed breakdown into nine skill levels, participants' scientific literacy level is low overall, as shown by their extremely low scores within each skill. There are several reasons for the low level of scientific literacy in the Lebanese context. Baltikian (2021) found that prospective teachers in Lebanon lacked scientific literacy. Science teachers have a significant impact on students' understanding of science, their interest in science, and their ability to foster scientific literacy. Considering that prospective teachers will eventually teach in classrooms, their low science literacy may restrict their ability to effectively convey science concepts, facilitate productive discussions, address students' queries, and clarify student uncertainties. It can greatly affect students' learning experiences and limit their exposure to scientific thinking and inquiry (Baltikian, 2021). Though students' first exposure to science occurs in school, scientific literacy is a lifelong goal. It is the responsibility of teachers to equip students with the skills and knowledge necessary for scientific literacy. Additionally, teachers must give students an understanding of how science works, as well as motivate them to value science education (Koballa et al., 1997).

Also, BouJaoude (2002) found that the Lebanese curriculum emphasizes science knowledge (aspect 1), science's investigative nature (aspect 2), and science's interactions with technology (aspect 4), but neglects science as a means of knowledge (aspect 3). Since science as knowledge (aspect 3) provides students with metacognitive tools to reflect on science as an enterprise, BouJaoude (2002) deems this problematic. It is necessary to acquire, understand, and apply a variety of skills in order to gain knowledge and skills. In order for students to be able to transfer their knowledge and skills to new situations, they must reflect upon the knowledge and skills they have acquired (BouJaoude, 2002).

Other important factors that must be considered include teaching, assessment, and textbook quality if students' experiences with science are to be complete and satisfying (Andriani et al., 2021; BouJaoude, 2002; Merta et al., 2020; Saraswati et al., 2021). Science textbooks are essential instructional tools in teacher-centered classrooms (Ogan-Bekiroglu, 2007). According to Yacoubian et al. (2017), Lebanese national science textbooks are heavily influenced by white male scientists of European descent. This is considered problematic, since non-western scientists, including Lebanese and/or Arab scientists, are almost entirely absent in textbooks. Textbooks should encourage diversity and social justice, and revision of science textbooks to address these issues is important to teaching since teacher's heavily rely on them (Ramnarain & Chanetsa, 2016).

Science education requires a variety of learning models, and inquiry learning is a critical part of improving scientific literacy skills. According to Nwagbo (2006) and Mutmainah et al. (2019), inquiry learning affects scientific literacy skills. To increase prospective teachers' scientific literacy skills, lecturers can introduce them to socio-scientific issues (Solli, 2021; Wu & Tsai, 2011). As described in Vasconcelos et al. (2018), socio-scientific issues is a method of learning that provides a context for discussions that deal with issues such as politics, economics, and ethics. Accordingly, socio-scientific issues also serve as a tool to contextualize these life issues in the context of building and improving scientific literacy skills (Kinslow et al., 2019). Besides scientific literacy, socio-scientific issues promote critical thinking and ethical reasoning (Arbid et al., 2020).

A Comparison of Science Literacy at Different Grade Levels

First, descriptive analysis of quantitative data (**Table 7**) revealed that grade 10 students achieved the lowest mean scientific literacy score (mean score of 11.00). Both grade 11 and grade 12 showed similar mean scientific literacy scores of 13, however one must be careful in interpreting this because the sample sizes are almost equal (18 and 17). Further analysis was conducted using Welch's ANOVA to determine whether there were statistically significant differences between grades. The results of Welch's ANOVA showed that there are statistically significant differences between grade levels (**Table 10**). As determined by Bonferroni post hoc analysis, grade 10 and grade 11 and grade 10 and grade

12 have significantly different levels of scientific literacy. In contrast, there is no significant difference in scientific literacy levels between grades 11 and 12.

Science Literacy Levels of Secondary School Students Based on Gender in Lebanon

Based on descriptive analysis, both genders scored similarly on scientific literacy at grade 10 (**Table 7**). In contrast, grade 11 and grade 12 males scored higher on scientific literacy than their female counterparts (**Table 7**). A Mann-Whitney U test was conducted to examine gender-based differences in scientific literacy levels. According to Mann-Whitney U statistics, there were no significant differences between the two genders (**Table 12**). In similar findings, Čipková et al. (2020) found that gender does not influence scientific literacy levels. Our findings contradict that of Shahzadi and Nasreen (2020) and Mukti et al.'s (2019), which suggest that girls performed better than boys. According to Shahzadi and Nasreen (2020), girls are more self-regulated, self-disciplined, hardworking, and persistent, which are essential elements in acquiring high literacy. Additionally, Caselman et al. (2006) found that girls performed worse than boys in scientific literacy levels. Based on the PISA reports of 2000, 2003, and 2006, it was determined that boys and girls had significantly different levels of scientific literacy. Among all countries, Finland was the only one that expected girls to perform better than boys (OECD, 2009).

CONCLUSIONS

Based on the findings of the present study, it was found that the scientific literacy levels of secondary school students in Lebanon are low. Methods of inquiry, data organization, data analysis, and interpretation are severely lacking among students. We also found statistically significant differences in scientific literacy levels between grade 10 and grade 11, and between grade 10 and grade 12. No differences were observed in terms of gender.

In light of these results, it is imperative that efforts are made to improve the scientific literacy levels of secondary school students in Lebanon. Science educators, Scientists, and policy-makers agree that fostering scientific literacy of students regardless of their desired future professional orientation is a fundamental aim of science education (Gormally et al., 2012; Harlen, 2010; Miller, 2006; UNESCO, 1999). Science education ought to inculcate students' capabilities in science and technology, particularly the capability to encounter difficulties, make educated decisions, develop coping strategies, and learn to live in the 21st century global community (Ibe et al., 2016). Considering these results, it is imperative that efforts are made to improve the scientific literacy levels of secondary school students. People's lives depend on scientific literacy skills in the 21st century, and socio-scientific issues are one approach to improving the scientific literacy skills of prospective biology teachers. This is not only in response to a lack of scientific literacy skills but also as a way of preparing students for global citizenship (Vasconcelos et al., 2018). Based on our results, we recommend strengthening the science curriculum with laboratory/practical activities that engage students in inquiry (Gormally et al., 2012; Leonard et al., 2001; Odegaard et al., 2015; Wilson et al., 2010). According to Diana et al. (2015), teachers can improve scientific literacy skills by presenting and teaching learning material that encourages higher-order thinking and contextual learning, including experiments that stimulate higher-order thinking.

This study adds to the existing literature by making culture-specific contributions to both research and practice in science education. The existing literature has gaps in assessing scientific literacy levels of secondary school students in general, and in the Lebanese context in particular. It is important to conduct more research, as this could have an impact not only on science education, but also on healthcare, environmental scientists, and journalists who report on scientific discoveries among others.

In terms of practice, this study can shed light on the need for developing an updated science curriculum that incorporates all aspects of scientific literacy, as well as updated science textbooks and other science educational resources to support the teaching and learning of such a curriculum. In the future, studies will be needed that cover schools from multiple regions in Lebanon and broaden the scope of the study. Studying in depth could replicate the present study, ensuring stronger generalization through systematic sampling. There are a number of questions raised in this study that are beyond the scope of this study yet call for further exploration. Future research can be recommended based on the results of this study. A research study is needed in the following areas: Focusing on strategies to improve Lebanese students' scientific literacy levels, investigating the factors contributing to different levels of scientific literacy, and conducting comparative studies across cultures between the Lebanese setting and other settings.

Research Limitations

There are some limitations to this research. One of the factors that might have affected the research results is the social and economic conditions of the research sample. All participants come from private schools. Several schools did not accept to participate in the research study, which was one of the limitations. In addition, the COVID-19 pandemic played a role in this since schools were online and focused on delivering curriculums. Therefore, convenience sampling was used in the study. As a result, the group sizes were impacted as well, although this was overcome by the choice of the statistical test. There should be careful consideration of the generalizability of the results, particularly in light of the cultural context.

Author contributions: All authors have sufficiently contributed to the study and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Ethical statement: The authors stated that the study did not require any ethical approval. In this study, data was collected through surveys. Survey responses were anonymous. Additionally, respondents' privacy and confidentiality were protected by maintaining anonymity and securely storing survey data, further mitigating ethical concerns. The authors further stated that the research adhered to the highest ethical practices. Participants were provided with a comprehensive explanation of the study's purpose and potential implications, and they willingly provided informed consent.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author. Each such request will be individually evaluated by the authors. In order to protect the privacy of and confidentiality of the participants, data will be anonymized before sharing.

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