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ORIGINAL ARTICLE

The Level of Scientific Argumentation Skills in Chemistry Subject among Grade 11th Students: The Role of Logical Thinking

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ABSTRACT

This study aimed at identifying the level of scientific argumentation skills in chemistry subject among Omani Grade 11th students and the effects of their logical thinking skills and gender on this level. The study sample consisted of (400) male and female students selected purposely from one educational region in Oman. The study's instruments consisted of "Scientific Argumentation Skills Test" and "Logical Thinking Test." The study results revealed that the level of grade 11th students was moderate in argumentation skills and was low in logical thinking. In addition, there were statistically significant differences at ($\rho < 0.05$) in scientific argumentation skills level due to gender in favor of female students. It also showed significant differences in logical thinking variable in favor of students with abstract thinking, and in the interaction between gender and logical thinking in argumentation level in favor of female abstract thinking. The study is important for Omani chemistry teachers because it gives an overview of the level of scientific argumentation skills and logical thinking skills among their students, which then helps the teachers in determining the next steps of the learning process by adopting appropriate teaching strategies.

KEY WORDS: Scientific argumentation skills; logical thinking skills; grade 11th students; gender

INTRODUCTION

The current age is characterized by rapid and successive changes in all aspects of life. People are facing different problems and issues related to their daily life that require them to take action and find solutions. One way to do this is to prepare the future generations through effective educational systems that preparing them to keep pace with developments; and moving from preserving scattered facts to developing thinking skills such as argumentation, inference, and interpretation of scientific phenomena (NGSS Lead States, 2014).

The use of scientific argumentation in teaching is of great importance as it makes the students' engagement more effective in the teaching and learning process, as it helps develop their ideas because they come to know themselves rather than presenting them in ready-made templates (Ratcliffe and Grace, 2003). Teaching individuals how to engage in discussions and use scientific evidence in these discussions is an important issue for the future of decision-making, especially when the students are faced with controversial issues (Ratcliffe and Grace, 2003). Therefore, science should play a critical role in developing future citizens with such skills (McNeill et al., 2006). Uncertainty in argument created productive moments for students to collaborate in dialogue and direct their understanding of natural phenomena toward more coherent scientific explanations (Chen et al., 2019).

LITERATURE REVIEW

Sampson and Clark (2008) defined scientific argumentation as "a process of building and consolidating conclusions based on reasons and explanations" (p. 66). However, Oliveira (2013) has a more elaborated definition of scientific argumentation and he defined it as "improving the ability of both students and the teacher himself to adhere to the quality of questions and discussion that can be chosen and formulated in an educational situation that includes the use of argument" (p. 422).

There are many reasons reported in literature to implement learning science using argumentation including developing students' understanding of the nature of science better (Boran, 2016), improving conceptual understanding of central scientific ideas (Shalaby, 2015), developing critical thinking and communication (Fulton and Poeltler, 2013) and training students how to acquire evidence-based decision-making skills in the context of social science issues (Zeidler et al., 2009).

Although there are many advantages achieved by developing students' scientific argumentation, it has not received much attention in teaching (Braund et al., 2013), and the opportunities given to the learner to build and participate in the argumentation have been limited (Newton et al., 1999). This contradicts the goals and objectives of teaching science that have undergone a wide change from learn to know to learn to do to learn to be (Venville and Dawson, 2010). Thus, learning

to "Be" is a broad meaning that requires a number of practices by teachers inside the classroom. These practices include: 1) learning to have an opinion and listening to the opinions and ideas of others; 2) discusses and makes allegations; 3) use evidence to justify the interpretation of the phenomena; 4) student's abilities to interact with others, and finally 5) student's ability to make decisions about the issues that require to take.

The essence of scientific argumentation is thus to make a claim, refine it, and then support it on the basis of scientific evidence. Scientists consume a great deal of time in assessing, critiquing, and defending their evidence to convince others in favor of their argument (Afifi, 2015). Thus, scientists have developed their potential to indulge in scientific argumentation. However, students require certain specific abilities in order to engage productively in scientific argumentation. The first is the ability to understand and use some sort of conceptual framework (theories, principles, laws, models, etc.) while reasoning about a scientific issue or problem. Second, the use of correct epistemology for evaluating a claim. Finally, the ability to construct and communicate knowledge as a social interaction process. The issue and question to be asked here are: Do the majority of students really possess the abilities required for engaging in scientific argumentation? Unfortunately, the answer to large extent is 'no' especially for those school students who struggle to find relevant data to support their claim and provide evidence (Sampson et al., 2013).

Faize et al. (2018) explained the process of involving students in argumentation. The first thing is the provision of suitable and stimulating learning environment such as problem-based or project-based learning environment. This may include socio-scientific issues that involve diverse responses and explanations. Second, the students should be provided with a clear set of instructions and information about the structure/components of argumentation. Third, the students should be encouraged to think and ask questions. Usually, controversial types of questions help more in setting the ground for discussion and cross-questions. This sets the pace for collaborative argument that encourages dialogic interaction and collaborative reasoning. Such kind of interaction makes the students support their views through valid evidence and challenging opposite views with countering ideas.

Several studies have been conducted to identify the importance of scientific argumentation in learning science. For example, González-Howard and McNeill (2020) found that incorporating argumentation into classroom instruction holds the promise of supporting students in developing and acting as knowledge agency, recruiting, and seizing opportunities to inform knowledge-building actions in the classroom community. To foster scholarly classrooms in which students play active roles, argue to learn, and co-create true meaning, the study suggested using multiple, and sometimes misleading, approaches to addressing the tensions inherent in helping students develop and work with cognitive agency. The study by Allchin and Zemplén (2020) confirmed that argumentation is an important component of the nature of science education and that the criterion here is the set of cognitive processes relevant to citizens and consumers as they assess the reliability of scientific claims in making personal decisions.

Ural and Gençoğlan's (2020) study aimed to investigate the effect of argumentation-based science teaching approach on 8th graders' learning of the subject of acids and bases, their attitudes toward science class, and their scientific process skills. Their results revealed that the argumentation-based science teaching approach was more effective than the didactic teaching approach while learning the subject of acids and bases. Moreover, the findings showed that the academic achievement of the students taught with argumentation-based approach was higher than the ones taught with didactic teaching approach. Finally, the findings found that the argumentation-based science learning had no significant effect on students' attitudes toward science class but it had a significant effect on students' science process skills.

Ping et al. (2019) sought to investigate the effects of incorporating explicit instruction of scientific argumentation through practical work on 10th grade students' skills in science process. The results of that study indicated significant differences in science process skills among the three groups (conventional group, experimental group with inquiry without argument approach group, and the modified argument-driven inquiry approach group), where students in the modified argument-driven inquiry approach group showed better performance compared to the other groups. The results have implication on researchers and practitioners keen on promoting biology science process skills through instructions of scientific argumentations given explicitly in learning environments of science practical work.

Sampson et al. (2011) used a series of lab activities in a form of argument-based inquiry (ADI) to prompt students' ways in participation in classroom inquiry. The results showed that students had better disciplinary participation and produced better reasons after their intervention despite of some learning problems that seemed to hinder the students' improvement.

Argument is an important part of higher-order thinking and logical analysis processes, and a base for individual thinking generally and thinking about scientific societal issues particularly. Thus, it is important to relate teaching argumentation to develop various types of thinking including logical thinking. Logical thinking is one type of scientific thinking that depends on perceiving and visualizing the relationships between previous information in order to reach certain conclusions regarding new, unknown situations. It can be developed through numerical or computational processing strategies, and problem-solving strategies, which are closely related to the skills of scientific argument (Makki, 2016).

There are different methods to measure logical thinking such as:

- Direct observation method: Used to observe and record students' work during their involvement in scientific activities.

- Self-report: Intended to give the students an idea of themselves, about their level of logical thinking skills.
- Psychological tests: Are "a set of standardized or controlled conditions presented with a specific design to obtain a sample of behavior in certain environmental conditions or requirements or in the face of challenges that require maximum effort or energy, and these conditions or challenges often take the form of verbal questions" (Faraj, 1980, p. 58).

One of the more well-known tests that measure logical thinking is the 'Test of Logical Thinking' (TOLT) which is developed by Tobin and Capie (1980). The final form of the TOLT consists of two items in each area of five domains: proportional inference, variable control, associative inference, probabilistic inference, and combinatorial inference. The current study used this test in its Arabic version. The TOLT was translated into Arabic by Abu-Roman (Al-Khawaldah, 2008).

Riyanti and Karyanto's (2019) study aimed at identifying the relationship between logical-thinking ability and science achievement of middle school students. The research data was collected using tests and observations, which were then analyzed using quantitative descriptive techniques. The results found that there was an insignificant relationship between logical-thinking ability and students' science achievement.

Makki's study (2016) aimed to determine the effectiveness of the proposed program based on the use of the argumentative approach in developing understanding of historical causation, and some logical thinking skills among second-grade students in the middle school in Aswan Governorate, Egypt. The results of the study showed that the experimental group performed better in application of the historical causation comprehension test and the logical reasoning test.

The aim of Okumus and Unal study (2012) was to examine the impact of the scientific argumentation on students' achievement and the development of their logical thinking skills in the unit (states of matter and heat). The results showed that scientific argumentation had positive effects on students' achievement and that logical thinking skills have been gradually developed through teaching.

Al-Khawaldeh study (2008) aimed at identifying the level of conceptual knowledge of photosynthesis, and its relationship to the level of logical thinking and attitudes towards biology. The results showed that there were statistically significant differences in acquiring conceptual knowledge due to logical thinking in favor of those with abstract thinking. Kuhn's study (2008), which aimed to design an online learning environment for learning genetics to develop argumentative skills at Columbia University in the United States showed that the development of argumentative skills has a good relationship with thinking, and contributes in developing more thinking skills. Participation of students in the argument process requires making meaning data, creating explanations for natural phenomena, justifying their explanations with scientific evidence, logical inference, and criticizing other points of view.

Finally, at local level studies such as (Al-Afifi and Ambusaidi, 2014; Al-Hadrami, 2012) have pointed a low level of students in logical thinking abilities and the presence of statistically significant differences in logical thinking between males and females in favor of males.

Chemistry Teaching at Sultanate of Oman

Chemistry is taught in the Sultanate of Oman in the form of simple format in the science book in the first cycle (grades 1−4) through which an introduction is made about the concept of matter, its states (solid, liquid, and gas), and their transformations. As for grades 5−8, chemistry is taught in separate units in the science book through different topics such as the composition of the atom, the electronic distribution, elements, compounds, solutions, mixtures, the periodic table, and the study of the properties of groups and the courses in it. At grades 9 to 12, there is a separate subject for chemistry and several topics are presented such as the properties of the elements (atomic size, ionization energy, electrical negativity), the shapes of molecules and their polarity, acids and bases, and the study of organic compounds (alkanes, alkenes, alkenes, alcohols, etc.) and their interactions and uses in various fields.

Research Problem and Questions

The use of scientific argument in teaching is of great importance as it makes the students' position more effective in the educational situation. It helps to develop their thoughts because they find knowledge by themselves instead of being presented without effort. Also, teaching individuals how to engage in discussions and use scientific evidence in those discussions is an important issue for the future of the decision-making process, especially in controversial issues (Ratcliffe and Grace, 2003). Science education plays a critical role in developing countries which will need it in the future for citizens with such skills (McNeill, et al., 2006). There are many advantages that scientific argument achieves, it has not received attention in the reality of teaching (Braund et al., 2013) and the opportunities which given to the learner to build participate in the argument are very limited (Newton et al., 1999). This inconsistency with the goals of teaching science which has a wide range of changing from learn to know, then learn to do, and then learn to be (Venville and Dawson, 2010). Learn to be has a broad meaning requiring a number of practices including learn to have an opinion, listen to and discuss other opinions and thoughts, make claims, use evidence to support them, interact with others, use evidence to justify your interpretation of phenomena, have the ability to make decisions.

Some studies also showed a decline in scientific argumentation skills in general (Nurinda et al., 2018; Sekerci and Canpolat, 2017). Several studies have found students' weakness in thinking skills in general and logical thinking in particular (Fah, 2009; Powell, 2000; Al-Hadrami, 2012; Al-Afifi and Ambusaidi, 2014). The results of some studies also showed the absence of statistically significant differences between

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males and females in the skills of scientific argument. (Hsu et al., 2018) Some studies also recommended the necessity of using scientific argument models to treat the problem of weakness in problem-solving skills and higher-order thinking skills (Al-Jamia, 2016).

The results of Chen et al. (2019) study showed that uncertainty in argument created productive moments for students to cooperate in dialogue and direct their understanding of natural phenomena toward more coherent scientific explanations. Uncertainty management has been productively affected by how to use students' cognitive understanding of the argument as a resource to create space for engaging in social negotiations.

To identify the research problem in-depth, the researchers conducted a survey, targeting 15 chemistry teachers in post-primary education grades (11−12) where closed and open questions were used, divided into two domains. The first one was to find out if students possessed the scientific argumentation skills whereas the second one was to identify students' logical thinking skills from the teachers' point of view. The results showed that 60% of the sample confirmed that the students did not have the skills of scientific argument, and the reasons behind this were the fact that the students did not have enough knowledge to enable them to argue plus they were not trained to do any argumentation by their teachers. Futhermore, 70% of the sample indicated that the most important reasons that hindered some teachers not to use argumentation inside the classroom were: 1) students were very weak in terms of their performance and 2) the limited time for applying such experience with the density of the content. Regarding the logical thinking abilities, the results showed that 55% of the teachers believed that their students did not have the skills of logical thinking. This was due to the fact that teaching was test-oriented and less emphasis was placed on teaching practices (teaching strategies and the development of thinking skills). In addition, 25% of the sample confirmed that they did not use teaching methods that develop logical thinking skills among their students, and one of the most important difficulties they faced was the lack of motivation of students to learn. With regard to the role of the scientific argumentation in improving thinking abilities, 75% of the sample believed that scientific argumentation played a major role in expanding students' perceptions and giving them a space to think, conclude, and realize the relationships between the information presented and linking the cause to the result. Therefore, the current research addressed the following questions:

1. What is the level of scientific argumentation skills among 11th grade students in chemistry?
2. What is the level of logical thinking abilities among 11th grade students?
3. Does the level of the scientific argumentation skills in chemistry differ according to the level of logical thinking and gender of students and the interaction between the two variables?

METHODOLOGY

The study used a survey approach, based on two tests: scientific argumentation and logical thinking that were administered to the participants in their schools.

The Participants

The target sample of the study was drawn from 11th grade students that chose to study chemistry. Students were selected using a convenience sampling method from 10 schools in one of the biggest educational authorities in Oman. A total of (400) male and female students completed the two tests with an equal number for each gender: 200 male and 200 female participants. The researchers obtained ethical approval to conduct the two tests from the Omani Ministry of Education. This Ministerial approval allowed the researchers to conduct this research without the need to get individual approval.

Research Instruments

The researchers used two instruments to gather the data from the participant. These were scientific argumentation and logical thinking.

Scientific Argumentation Skills Test (SAKT)

The aim of this test was to find out the level of scientific argumentation skills among students in issues related to chemistry learning. The researchers followed the following steps to generate the test.

1. Reviewing educational literature and previous studies related to the subject and benefiting from some of the phrases mentioned in some studies (Afifi, 2015; Al-Jamia, 2016; Khishfe, 2012).
2. Confine the controversial topics in the subject of chemistry by reviewing organic chemistry in the first chapter of the Omani chemistry textbook for grade eleven. Two topics were chosen from it as it relates to the student's life. These were: argumentation about the use of ethylene in fruit ripening and argumentation about using plastics.
3. Preparing the test in its initial form, which included six questions that were divided into three scientific argumentation skills:
    - Providing a claim: two questions.
    - Providing of evidence: two questions.
    - Providing of justification: two questions.

The following are examples of the problem presented to students:

- What would happen if we stopped using ethylene gas to ripen fruits?
- What would happen if we stopped using plastic in our lives?

After that, the test was given in its primary form to eleven specialists in curriculum and methods of teaching chemistry, school supervisors of science, or teachers of chemistry to check its validity. Based on their opinions, the test was amended for some questions, clarifications, and translation of the drawings. To calculate the reliability of the test, it was administered to a sample consisting of 33 students from the eleventh grade

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studying chemistry outside the main sample. Alpha Cronbach coefficient for internal consistency was used to find out the reliability value of the test. It was found that the value of the coefficient was 0.83, which was considered an acceptable for the purposes of the study.

During the piloting process, the researchers calculated the time needed to answer the questions and it was found to be 40 minutes. After the administration of the test to the 400 students, a sample of students' papers (15 papers) was taken and marked by two markers to check interrater reliability using the Pearson correlation coefficient, which was found to be 0.91. This value of coefficient was considered educationally acceptable for the purpose of the study.

A rubric was designed to mark student's answers for each question. This rubric was checked by the experts during the validation process. Table 1 shows the designed rubric to mark the questions of the scientific argumentation test.

Test of Logical Thinking (TOLT)

The aim of this test was to identify the level of logical thinking skills in chemistry for eleventh graders**.** The researchers adopted Tobin and Capie (1980) test, which was translated into Arabic by other researchers and then further modified and applied to the Omani environment by Al-Hadrami (2012). It is a multiple-choice questions (MCQs) instrument in which students were asked to select the right answer from given options. The test consists of four skills. These are proportional reasoning, control of variables, probabilistic reasoning, and associative reasoning. Each skill consists of two questions and each question worth two marks so the total mark was 16. The following is an example from the test:

For example Four oranges are squeezed to make six cups of juice. How much juice can you get from squeezing six oranges?

a) 7 cups, b) 8 glasses, c) 9 glasses, d) 10 glasses, e) 12 glasses

In order to check the reliability of the test, it was applied twice to a sample consisting of 33 students from the same grade, and the Pearson correlation coefficient was calculated. The value of the coefficient was found to be 0.75 which was considered educationally acceptable for the purposes of the study. During the piloting of the test, the researchers calculated the time needed to answer the questions and it was found to be 30 minutes.

Data Analysis

The Statistical Packages for the Social Sciences (SPSS) version 20 was used to analysis the data. For research questions, one and two mean values and standard deviations were calculated. For third question, MannWhitney test was applied as the sample distribution is not normal.

FINDINGS

Research Question One

What is the level of scientific argumentation skills among 11th grade students in chemistry?

In order to answer the first research question, mean values and standard deviations were calculated for each skill and it is presented in Table 2:

As it can see from Table 2 that 'provide a claim' skill had a higher mean value and it was ranked as high level, which means that these Omani students possess this skill to a high level. Then, provide evidence' skill with medium level and finally 'provide justification' skill with low level. In addition, mean value of each question in the three skills was also calculated and presented in Table 2.

It can be seen from Table 3 that the mean values of 'provide a claim skill' questions were 2.26 and 2.21, which is higher than the mean values of both 'provide evidence' and 'provide justification' skills domains questions.

Research Question Two

What is the level of logical thinking abilities among 11th grade students?

To answer this question, the mean values and standard deviations were calculated for each of the skills of the logical thinking test (Table 4).

The results in Table 4 show that the mean values of the logical thinking test was 7.72 which is very low (less than 50%).

Table 1: Rubric of correcting scientific argumentation test

Scientific argumentation skills	Mark			
	0	1	2	3
Provide a claim	The student does not provide information to support the claim	The student provides one piece of information to support the claim	The student provides two pieces of information to support the claim	The student makes more than two predictions of what will happen in the case at hand
Provide evidence	The student does not provide information to support the Evidence	The student provides one piece of information to support the Evidence	The student provides two pieces of information to support the Evidence	The student provides more than two information to support the claim
Provide justification	The student does not provide information to support the Justification	The student provides one piece of information to support the Justification	The student provides two pieces of information to support the Justification	The student provides more than two links between the claims and the evidence

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Table 2: Mean values and Standard deviations for the level of performance in each skill of scientific argumentation test

Scientific argumentation skills	M	SD	Level
Provide a Claim	2.23	0.64	High
Provide Evidence	1.89	0.72	Medium
Provide Justification	1.36	0.55	Low
The test as a whole	5.48	0.55	Medium

*Low (1−1.66) medium (1.61−2.33) high (2.34−3.00)

Table 3: Mean value and standard deviation for scientific argumentation test questions

Skill	Question	M	SD
Provide a claim	What happens if we stop using ethylene gas to ripen the fruits?	2.26	0.76
	What happens if the world stops using plastic?	2.21	0.75
Provide evidence	Use as much data as possible to support your claim on the ethylene gas used issue.	1.90	0.84
	Use as much data as possible to support your opinion on the plastic use issue.	1.88	0.85
Provide justification	How do you link a claim in the ethylene case with appropriate evidence?	1.33	0.61
	How do you link a claim in the plastic case with appropriate evidence?	1.40	0.67

Table 4: Mean value and standard deviations for logical thinking skills

Skill	Total Mark	M	SD	%
Proportional thinking	4	2.03	1.52	51
Control variables	4	1.35	1.49	34
Probability thinking	4	2.28	1.3	57
Associative reasoning	4	1.88	0.79	47
Test as whole	16	7.72	3.54	48

Regarding each skill, it is evident from the table that these students' performance in the test overall was very low, only in proportional thinking and probability thinking skills, did these students performed slightly higher than 50%.

Research Question Three

Does the level of the scientific argumentation skills in chemistry differ according to the level of logical thinking and gender of students and the interaction between the two variables?

To answer this research question, a Man Whitney test was used, in which the 'mean values' were calculated and compared of students' performance in scientific argumentation test with their performance in the logical thinking test and their gender. Table 5 shows the results of the logical thinking test (physical and abstract). The sample was divided into physical and abstract levels according to the mid-value of the test (8/16) of the logical thinking test. Students who scored less than 8 were classified to be physical and those who scored 8 and above were classified to be abstract.

It is clear from the results of Table 5 that there were statistically significant differences at the level (0.001) in students' scientific argumentation skills due to their logical thinking level in favor of abstract thinking, Regarding the gender differences, Table 6 shows the results of the ManWhitney test for this variable.

As it is shown in Table 6 that there were statistically significant differences at the level (0.001) in the three skills of scientific argumentation and the test as whole due to gender variable in favor of female students.

DISCUSSION

The results of the study indicate that the level of scientific argumentation skills among these participating eleventh-grade students was medium. This could be explained that these students have not been exposed to many activities

Table 5: Results of MannWhitney test in scientific argumentation skills due to logical thinking patterns

Source of contrast	Thinking level	No. of Students	Average rank	Total Ranks	Value of Man Whitney	Sig. level
Scientific argumentation	Physical	206	165.94	34183.50	12862.50	0.001
	Abstract	194	237.20	46.16.50		

Table 6: Results of MannWhitney test in scientific argumentation skills due to gender differences

Source of contrast	No. of Students	Average Rank	Total Ranks	Value of MannWhitney	Sig. level
Provide a Claim	Male	167.85	33516.50	13416.5	0.001
	Female	233.42	46683.50		
Provide evidence	Male	156.72	31344.00	11244.0	0.001
	Female	244.24	48856.00		
Provide justification	Male	169.85	33970.00	13870.0	0.001
	Female	231.15	46230.00		
Total test	Male	155.49	31098.50	10998.5	0.001
	Female	245.51	49101.50		

during chemistry teaching relating to scientific argumentation. Thus, if students were given opportunities for such activities, then this will increase their ability to provide claims, give evidence, and justifications (Fulton and Polter, 2013). Students' acquisition with scientific argumentation contributes to generating ideas and providing different solutions for the issues that are presented to them (Aleixandre and Periero, 2002). In addition, students' immersion and participation in the scientific argumentation contributes to shaping their learning and reaching the higher levels of argumentation (Al-Harthi, 2014), and leads to the development of their ability to scientific interpretation and analytical thinking (Hussam El-Din, 2011). Scientific argumentation can be enhanced by providing students with meaningful knowledge about the subject, which they argue in order to help them to develop logical evidence to support their claims (Khishfe, 2012). Patronis et al. (2010) argued that students were more able to develop argumentation skills and reach decisions when they are faced with a situation that affects their reality. As for their shortcomings in some of the skills of scientific argument such as justification, it might be due to the lack of understanding of the scientific argumentation terms (claim-evidence-justification) among students, which are very important in building the scientific argumentation (Martin and Hand, 2007).

Therefore, the teacher's use of scientific controversy terms such as allegations, evidence, and justification is necessary by introducing this language in science classes, as science teachers play a fundamental role in students' learning and imparting them to various skills. Duschl et al. (2007) argued that basic training in the sciences should include the use of evidence, creation of interpretations, and participation in controversy. And that there is a need to move science beyond a mere focus on practical activities to participate in an investigation in which students need to support scientific claims with evidence, build arguments and give explanations.

Regarding students' performance in logical thinking test, which showed to be very low for these students, this could be due to the fact that chemistry teachers are not willing to develop these skills as they are more focused on covering the dense content of the textbook (Al-Astal, 2006). In addition, there was less use of teaching strategies that train students in thinking skills (Hadrami, 2012). It was found that using inquiry-based teaching and problem solving will develop logical thinking abilities among students (Towne, 2009; Yaman, 2005). Moreover, the assessment process in Omani schools at grade 11 focus mainly on assessing students grasp of scientific knowledge (concepts, theories, and laws) and less focus on assessing the thinking skills (Al-Afifi and Ambusaidi, 2014).

These results showed that students performed better in proportional thinking probability thinking skills compared to other two skills of control variables and associative inference. This might be because students at grade eleventh possess the mathematical skills that enable them to solve any problems related to proportion and probability. Students at grade eleven study one book chapter or unit in math subject about probability, which may be what allows them to solve problems that required probability. Here, it is very important to highlight the importance of integration between science and math which will help students perform well in science if their mathematical skills are excellent (Al Orime and Ambusaidi, 2011).

As for associative reasoning skill in which students performed less well, this could be explained by the two questions representing this skill which required accurate calculations based on the pictures, and this may present a difficulty for the students because they need a high ability to calculate a set of ratios, and then compare them to determine the correct probability. Controlling the variables got the lowest mean values in the test and it seems that students are facing very big difficulty. It could be because students were not exposed to many activities or experiments that required them to determine the different sort of variable. There is a need for more training to students in this sort of experiments so that they will be able to solve problem related to control variables (Al-Hadrami, 2012).

The results emphasize the important that students possess the logical thinking skills in order to solve the scientific argumentations questions (Al-Khatib and Al-Ashqar, 2013). If students possess the logical thinking skills, then this would help them free their mind from any bias, rigidity, and adherence to its opinions, and help them to adhere to accuracy, objectivity, acceptance of criticism, and not to rush to make decisions (Makki, 2016). A student who has the ability to use abstracts and deal with proportions and numbers possesses a higher level of skills of scientific argument than colleagues who possess a physical level of logical thinking. The individual with abstract thinking is likely to have inquisitiveness, open-mindedness, cognitive maturity, fact seeking, and self–confidence (Barakat, 2007).

The results of the current study highlight that these female students outperformed in science compared to male students. It seems that these female students possess a higher ability to focus and analyze more deeply the issue at hand, in addition to the self-motivation to assert their personality, and the use of metacognitive processes consciously in organizing learning activity (Gad Allah and Alraqad, 2015). In addition, these female students were rated higher than the participating male students in verbal communication, as they were better in both using words to express ideas and linking ideas together (Momani, 2018; Muhammad, 2016; Ryan, 2013). This is known as linguistic intelligence. There is a strong connection between thinking and language. Thinking grows with language, and language develops thinking and high person's linguistic intelligence will increase their ability to think and understand (Tawfiq, 2015). The results also can be seen from the school environment for both male and female students. Female schools in Oman are more supportive to students compared to male schools. Female teachers are given more encouragement and motivation to support students to achieve well through using different teaching strategies and new

technology support materials. This is reflected in many areas such as students' achievements in TIMSS study, higher grades in upper secondary school, and more female students entering higher education compared to male students.

CONCLUSION AND RECOMMENDATIONS

The results of the study found that the level of scientific argumentation skills, in general, was average for eleventh-grade students in the subject of chemistry. However, for the logical thinking skill, the level was low. In addition, there was a statistically significant difference in the variables of scientific argumentation skills due to the level of logical thinking in favor of abstract-thinking student and due to gender in favor of female. The number of male students with concrete thinking was higher than the number of male students with abstract thinking, while the number of students with abstract thinking was higher than the number of students with physical thinking.

Based on these results, this study recommends that teachers should encourage argumentation based on dialogue and constructive discussion among students during the learning process. Furthermore, the teacher's guide in chemistry needs examples of lesson plans on how teachers can implement activities based on dialogue, debate, analyze opinions, and explain scientific issues, and link them to their students' life situations. Furthermore, train in-service teachers, in how to develop scientific argumentation skills among their students. For preservice teacher education, thorough teaching methods courses are needed, as student teachers should study and train on how to use the scientific controversy and argumentation type of teaching in the science classes.

Finally, further research is needed in the area of scientific argumentation and logical thinking. The current study recommends researchers conduct studies to find out the effect of using a teaching model based on scientific argumentation to develop students' thinking and acquiring of scientific argumentation skills. In addition, to determine the effect of a training program based on scientific argumentation in developing their argumentation skill and how this reflects on developing students' argumentation skills.

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