Int J of Sci and Math Educ (2016) 14:1003–1019
DOI 10.1007/s10763-015-9646-1

# Scientific Reasoning and Its Relationship with Problem Solving: the Case of Upper Primary Science Teachers

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Received: 1 April 2014 / Accepted: 14 April 2015 / Published online: 13 May 2015


**Abstract** This study aimed at identifying the levels of scientific reasoning of upper primary stage (grades 4–7) science teachers based on their use of a problem-solving strategy. The study sample ($N$=138; 32 % male and 68 % female) was randomly selected using stratified sampling from an original population of 437 upper primary school teachers. The scientific reasoning test was based on a problem-solving strategy and consisted of five parts (32 items) covering basic problem-solving skills. Descriptive and inferential statistics were used to interpret the data. Results indicated that the level of scientific reasoning of these science teachers was high with significant gender differences ($p \leq 0.05$) on levels of scientific reasoning that favored the female teachers. The results also showed no significant differences ($p > 0.05$) in scientific thinking among teachers with different experiences, qualifications, and specializations. These results support holding professional development courses for teachers to develop their scientific reasoning and thinking skills.

**Keywords** Grades 4–7 · Problem solving · Science teacher · Scientific reasoning

## Introduction

Problem solving has a prominent place within scientific reasoning because of its impact on changes and increasing emotional, cognitive, and psychomotor development. The American Association for the Advancement of Science (1993) emphasizes this relation between thinking and problem solving and considers problem solving to consist of basic processes, strategies, and knowledge resources. A special feature of scientific reasoning—organized thinking used in our daily lives whether at work or in other contexts—is the "intentional knowledge-seeking and coordination of theory and evidence" (Mayer,

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Sodian, Koerber & Schwippert, 2014, p. 43). Researchers approach scientific reasoning as a matter of exchanging and acquiring knowledge to produce, investigate, and revise theories and hypotheses (Kuhn & Franklin, 2006; Wilkening & Sodian, 2005). Such reasoning is based on a set of principles applied by individuals that emanate from their scientific knowledge and includes problem solving and thinking about a specific, naturally occurring event or phenomenon in an orderly and cumulative manner (Abdul Aziz, 2007; Kuhn, 2002). Furthermore, it is a mental process employed by individuals using their expertise, previous experiences, and mental abilities to infer and understand problems and difficulties encountered in order to reach conclusions and make decisions (Zimmerman, 2007). It is believed that scientific reasoning needs to be promoted early and developed over the following years of schooling using a problem-solving context. Therefore, it is important to ensure elementary school teachers of science have sufficient background in problem solving and scientific reasoning to enable such opportunities. This study explored elementary teachers' proficiencies in problem solving and reasoning using an instrument designed to assess their scientific reasoning within a problem-solving context.

## Background

The curricular function and instructional role of scientific reasoning and problem solving are to encourage students' engagement with learning science. The success of such an approach is dependent on teachers' understanding of scientific reasoning and problem solving and their ability to motivate students' development of these abilities.

### Scientific Reasoning

Scientific reasoning is of central importance because doing and learning science involves a wide range of scientific and engineering practices in constructing evidence-based knowledge claims and solutions, such as asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, engaging in empirical arguments, and obtaining, evaluating, and communicating information (National Research Council [NRC], 1996, 2012). These science practices subsume a number of basic processes, skills, and abilities (e.g. observation, measurement, inference, predication, classification, controlling variables, scientific language, critiquing solutions and explanations, using logic, etc.) that are particularly important because acquiring these processes, skills, and abilities can encourage students' continued engagement in many fields and learning domains (Ross, Lakin & Callaghan, 2004). Furthermore, scientific reasoning is necessary to prepare individuals for everyday life and citizenship to address and solve socioscientific problems facing their society or to critique proposed solutions (NRC, 2012; Osborne, 2013).

Scientific reasoning positively affects students' learning of science (Coletta & Philips, 2005). Specifically, Chen & She (2015) found that grade 5 students with explicit scientific reasoning support demonstrated significantly more testable and correct hypotheses, evidence-based explanations, and levels of scientific reasoning than comparable students without such scientific reasoning support. Their experimental group students also retained significantly more of their conceptual achievement and inquiry abilities over the control group students.

Abdul Aziz (2007) pointed out that there is a set of processes and traits that characterize scientific reasoning: accumulation, regulation, searching for causes, comprehensiveness and certainty, precision, and abstraction. Moreover, effective scientific reasoning needs deductive and inductive skills. Specifically, individuals should be aware of how to evaluate "what is currently known or believed, develop testable questions, test hypotheses, and draw appropriate conclusions by coordinating empirical evidence and theory" (Morris, Croker, Masnick & Zimmerman, 2012, p. 62). Such reasoning also requires the ability to attend to information systematically and draw reasonable inferences from observed patterns. Furthermore, it requires the ability to assess one's reasoning at each stage in the process.

There are a number of instruction experiences that help develop scientific reasoning (Nashwan, 2005): first, stimulation—using stimuli, words, or deeds to extend the opportunities and resources available to the student in the process of learning, which also encourages and promotes creativity; second, exploration—taking decisions and actions to access new knowledge; and third, planning—putting a plan in place and enacting its steps to develop new knowledge. An-Nimer (2003) described processes that encourage or impede students' use of scientific reasoning. Processes that *encourage* the use of scientific reasoning include urging students to search for scientific information outside school textbooks, focusing on scientific thinking and problem-solving skills, getting away from indoctrination, requiring students to clearly explain and raise scientific inquiries and questions, considering quality rather than quantity in the teaching/learning process, using different methods to teach scientific facts including field trips, and starting from students' experiences to increase their active role in the development of scientific reasoning. On the other hand, there are some processes that *impede* the development of scientific reasoning: intolerance of teachers for students' divergent opinions; intolerance of parents and teachers toward students' questions by ignoring them and giving insufficient answers; expecting children to follow the requests of adults with blind obedience and without discussing these requests, which limits and confines their ability to think; traditional test items prepared to elicit a single correct answer; providing students with ideas, observations, and solutions they can get themselves; not encouraging students to employ careful observation or critical thinking; and the way teachers are educated in colleges and universities, which makes them abandon or ignore the scientific thinking approach in their teaching.

Acar (2014) examined how scientific conceptions influence preservice teachers' scientific reasoning. The results showed that there were scientific reasoning, situational knowledge, and achievement differences between the two groups at the beginning of instruction. Instruction based on argumentation-based guided inquiry helped these groups reduce the situational knowledge and achievement gaps, but the scientific reasoning gap existed after the instruction.

## Problem Solving

Problem solving is frequently described as strategic step-wise procedure: (a) defining the problem, which entails identifying what it is that needs to be solved; (b) analyzing the problem, which entails scrutiny and investigation of the problem; (c) collecting appropriate data, which entails collecting data to help solve the problem; (d) formulating possible solutions, which entails identifying a wide range of initial, possible, or tentative solutions to the problem; (e) evaluating possible solutions, which entails weighing the advantages and disadvantages of each solution, including how, when, and where to accomplish each; and (f) choosing the best solution and generalizing the results, which entails verifying the results and their generalization to other similar cases (Harithy, 2000). This step-wise approach can be flexible, where problem solvers use a much more varied sequence of these procedures.

Problem solving can be enhanced by context-based learning that may effectively enable students to establish a complete problem-solving process (Yu, Fan & Lin, 2014). When problem solving involves science learning, there are many similarities with the applications of scientific reasoning (Ediger, 2013). Moreover, problem solving helps students make connections between science concepts by actively working with rather than by passively receiving solutions (Chen & She, 2015; Gallagher, 1997). The use of problem solving to enrich students' learning requires teachers' awareness, understanding, and support in their teaching (Chen & She, 2015; Gertzman & Kolodner, 1996).

## Teachers' Scientific Reasoning and Problem Solving

Researchers have found inconsistent results for teachers' and university students' scientific reasoning ability related to background variables. Nawawra (2012) found (a) that teachers of upper primary schools had a moderate level of scientific thinking; (b) nonsignificant differences among teachers with various years of experience, qualification, and specialty; and (c) a significant gender difference favoring female teachers. However, Abu Thoaeb (2005) found significant differences in teachers' scientific thinking in favor of teachers who taught scientific subjects and who had ten or more years' experience. Furthermore, Al-Haddabi, Al-Folfili & Al-olaibi (2011) reported a low level of scientific thinking and nonsignificant differences among university students across science departments and a significant gender difference favoring female students.

Furthermore, researchers have found inconsistent problem-solving ability and dispositions of teachers and university students related to background variables. An-Najjar (2009) found that teachers' ability to solve problems was generally good and found a significant gender difference in favor of females but no differences in terms of qualification. However, Al-Jobaili (2013) found that the ability of preservice teachers to solve problems was moderate and there were no significant gender differences. Yenice (2011) studied preservice science teachers' critical thinking dispositions and problem-solving skills and found nonsignificant gender differences in problem solving. Tümkaya, Aybek & Aldağ (2009) found that a more positive disposition toward critical thinking of university students was associated with higher levels of problem-solving skills. They found nonsignificant gender differences in both critical thinking disposition and perceived problem-solving skills, nonsignificant differences in problem-solving skills, but significant differences in critical thinking dispositions for students with different specialties. Moreover, there were significant differences in both problem-solving and critical thinking dispositions for students in different years of university study and specialization. Tümkaya et al. (2009) also found nonsignificant gender differences in critical thinking among university students.

Modern societies ascribe special status to scientific reasoning and problem solving as major ingredients in progress and development and as an indication of achieving high-quality education outcomes. Specifically, scientific reasoning attracts the attention of science educators and researchers for its positive influence on students' learning of scientific concepts (Gaio, Moyses, Besinelli, Franca, & Moyses, 2010). This is also the case with problem solving, where the ability to solve problems, especially complex ones, is one of the main competencies expected in science doing and learning (Scherera & Tiemann, 2014). An important issue flowing from this ascribed status is the relation of teachers' problem solving with their scientific reasoning. This study examined the relationship between teachers' use of problem-solving strategies and their scientific reasoning in the science classroom. Furthermore, this study investigated the impact of gender, qualifications, years of experience, and specialty on level of scientific reasoning based on the problem-solving strategy of upper primary school science teachers. The following research questions (RQ) guided the design, data collection, and analysis:

1. What is the level of scientific reasoning based on a problem-solving strategy among science teachers at the upper primary school?
2. Are there statistically significant differences in scientific reasoning based on a problem-solving strategy between science teachers of upper primary schools due to gender, years of experience, qualifications, and specialization?

## Methodology

This study was a survey of an intact population of upper elementary teachers who taught science. It used a descriptive approach commonly used in similar studies that examined participants' abilities, skills, or views. Tajudin et al. (2012) used a descriptive approach to map the level of scientific reasoning skills to instructional methodologies among sciences, mathematics, and engineering undergraduates. Similarly, Huang, Wu, She & Lin (2014) used a descriptive approach to study how using Facebook™-based Scientific News enhanced students' views of the nature of mathematics and science knowledge.

### Research Context, Population, and Sample

The population of the current study consisted of all teachers teaching science in the upper primary school (grades 4–7) during the 2012–2013 academic year. The research sample consisted of 138 teachers (32 % of the population) assigned to teach upper primary science courses in governmental schools of the Khalil District, south of Palestine. These teachers were randomly selected, according to stratified sampling using gender, teaching specialty, and teaching experience. The teachers were approached following the consent and authorization of the school district authorities as informed volunteers. The sample of participating teachers of science was distributed, regarding the different background variables, reflecting the teaching population of teachers in upper primary schools across the district. Table 1 illustrates that the participants were reasonably representative of gender, qualification, and teaching experience; however, the specialty clusters revealed a unique distribution where the literary stream had only 10 participants while the scientific stream had 128 participants. This imbalance was attributed to the fact that the Ministry of Education had

**Table 1** Sample distribution ($N$=138) according to gender, specialization, years of experience, and qualifications

| Variable | Level | Number | Percentage |
|---|---|---|---|
| Gender | Male | 69 | 50 |
| | Female | 69 | 50 |
| Specialty | Scientific stream | 128 | 92.57 |
| | Literary stream | 10 | 7.25 |
| Qualification | Diploma | 18 | 13.04 |
| | Bachelor's degree | 99 | 71.74 |
| | Higher than a bachelor's degree | 21 | 15.22 |
| Years of experience | Less than 5 years | 28 | 20.28 |
| | 5–10 years | 36 | 26.08 |
| | More than 10 years | 74 | 53.64 |

started to exclude teachers with literary backgrounds from teaching science at all levels.

## Data Collection

The researcher utilized an established scientific reasoning questionnaire (Nawawra, 2012) that is connected to the problem-solving strategy. This 32-item, multiple-choice questionnaire (one score per item for a total maximum score of 32 points) covered five basic thinking skills connected to problem-solving phases: problem identification (eight items), hypothesis formation (six items; maximum score six points), testing hypotheses (six items), interpretation (six items), and generalization (six items). Each multiple-choice item had three alternatives; the correct response was scored as one point. The questionnaire consisted of two parts: (a) personal data including gender, specialty, years of experience, and qualifications and (b) test items (see Appendix). The questionnaire could be considered a holistic measure of scientific reasoning.

## Questionnaire Validity

The questionnaire's content validity was explored by a panel of five expert referees who were asked to critique the questionnaire as to whether the items measured the specific basic thinking skills and to suggest any necessary modifications. All the referees approved the questionnaire and assured that its items were valid and relevant to the identified tasks. The construct validity of the questionnaire was examined through confirmatory factor analysis (CFA), where all the items with a loading value >0.4 on the prescribed thinking subscale were taken as confirming the structural validity. CFA results revealed that all items significantly ($p$<0.01) loaded on their preassigned factors (loading values=0.62–0.75). The questionnaire was also tested for item relevance; the 32 items demonstrated significant ($p$<0.01) relevance coefficients between 0.84 and 0.96. These psychometrics supported that the questionnaire can be assumed to be valid for the research focus of this study (Al-Masaeed, 2011).

### Questionnaire Reliability

The reliability of the questionnaire was explored using internal consistency. Cronbach's alphas were computed for each area of the questionnaire and the whole questionnaire. Cronbach's $\alpha$ was found to be 0.77 for problem identification, 0.82 for choosing hypotheses, 0.78 for testing hypotheses, 0.80 for interpretation, 0.83 for generalization, and 0.81 for the total questionnaire. These internal consistency values can be taken as good reliability for the questionnaire and its subscales (Al-Masaeed, 2011).

### Data Analysis

Descriptive statistics (averages, standard deviations, and percentage correct for each problem-solving stage) were computed to address the two research questions. *t* tests and ANOVA were conducted to explore the differences in the binary-value variable (gender) and main effects for the three-category variable (experience).

## Results and Discussion

### Research Question 1

The first RQ of the study was *What is the level of scientific reasoning based on problem-solving strategy of the participating grades 4–7 science teachers*? The mean, standard deviation, and percentage correct for each problem-solving stage were computed and are summarized in Table 2. The percentage-correct score was measured by dividing the mean by the total possible points for the subscale; the judgment about performance was based on the following criteria: ≤40 %=very low, 40–50 %=low, 50–60 %=moderately low, 60–70 %=moderate, 70–80 %=moderately high, 80–90 %=high, and ≥90 %=very high. We divided the low-to-high range of 40–90 into five equal intervals fitting the performance levels of low, moderately low, moderate, moderately high, and high.

The results show that the level of overall scientific reasoning of these upper primary teachers of science was judged to be high. All subscale percentage-correct scores, between ~63 and ~90 %, were judged as moderate to very high. The highest performance was for the interpretation subscale; the lowest performance was for the problem

**Table 2** Descriptive statistics (means, standard deviations, percentage correct) for the problem-solving questionnaire

| Subscale | *n* | *M* | SD | Correct (%) | Judgment |
|---|---|---|---|---|---|
| Problem identification | 8 | 5.06 | 1.56 | 63.25 | Moderate |
| Choosing hypotheses | 6 | 4.33 | 1.47 | 72.17 | Moderately high |
| Testing hypotheses | 6 | 4.42 | 1.59 | 73.66 | Moderately high |
| Interpretation | 6 | 4.52 | 1.29 | 75.33 | Moderately high |
| Generalization | 6 | 5.39 | 1.44 | 89.83 | Very high |
| Total | 32 | 23.72 | 7.35 | 74.12 | Moderately high |

identification subscale. Results show standard deviations that were reasonably large due to the variability of the scores, which ranged from 16 to 31 for the total problem-solving task, 1–8 for the problem identification subscale, and from 1 to 6 for the other subscales. These results were consistent with those of Al-Jobaili (2013), Nawawra (2012), and Al-Masaeed (2011), which showed science teachers demonstrated a more than moderate performance level for scientific reasoning, but were inconsistent with those of Abu Thoaeb (2005) who reported a lower level of teachers' problem solving.

The current results are attributed to the nature of the science curriculum that served as the framework for this study. The Palestinian curriculum (Palestinian Curriculum Development Center, 2014) is modern and has been designed and planned to include learning activities, teaching methods, and assessment approaches that support the development of different kinds of thinking skills among teachers and students. The Palestinian teachers of science, due to the new curriculum, use teaching strategies that emphasize the personal development of the learner in all aspects. Moreover, the Ministry of Education, together with Palestinian universities over the last 3 years, has held different workshops and implementation programs for inservice teachers to support their professional development. These programs focus on learner-centered education, and these efforts appear to be enhancing the level of the teachers' scientific thinking skills demonstrated in this study.

## Research Question 2

The second RQ was *Are there statistically significant differences in the level of scientific reasoning based on a problem-solving methodology between science teachers of upper primary schools attributed to gender*, *years of experience*, *qualifications*, *and specialization*? The questionnaire's results were explored with a series of statistical tests.

Potential gender differences were explored with $t$ tests using means, standard deviations, and effect size for the specific groups of teachers of science; results revealed significant differences between the means of the overall scientific reasoning favoring the female teachers, female $M=22.89$, SD=5.97; male $M=21.18$, SD=6.82; $t=2.00$, $p=0.03$, ES=0.13. The $t$ test results of the subscales revealed significant differences in favor of the female teachers for two subscales: (a) problem identification, female $M=21.95$, SD=4.17; male $M=19.84$, SD=5.12; $t=2.11$, $p=0.02$, ES=0.22, and (b) interpretation, female $M=23.46$, SD=5.34; male $M=21.49$, SD=4.67; $t=1.97$, $p=0.05$, ES=0.19. The $t$ values and effect sizes indicate that the significant difference due to gender is small and should be taken in a limited way. These results agree with those of Nawawra (2012) and An-Najjar (2009) but disagree with those of Al-Jobaili (2013), Al-Masaeed (2011), and Gha'eb (2011), who did not find significant gender differences in scientific reasoning. These variations in gender findings may be due to the variation of educational program contexts and the adoption or nonadoption of modern, learner-centered teaching methods aimed at promoting females' and males' cognitive skills.

The experience main effects on scientific reasoning were examined using a one-way ANOVA where years of teaching experience were the independent variable and scientific reasoning was the dependent variable. ANOVA results revealed a nonsignificant main effect, $F=1.47$, $p=0.29$; however, an increase in years of experience was associated with an increase in scientific reasoning. Similar nonsignificant experience main effects were obtained for the different subscale responses. These results were consistent with those of Nawawra (2012), despite the different populations studied, probably because the two studies used similar teaching strategies. However, the results were inconsistent with those of Al-Masaeed (2011), probably because of the difference in populations studied, that is, university students and primary school teachers. The primary school teachers participating in the current study apparently continued to develop themselves and keep in touch with modern teaching methods and technological advances as a responsibility of their teaching assignment. This professional development of the primary teachers is consistent with the core of the constructivist theory of cumulative knowledge gained through the increased expertise and interactions taking place in social context or a community of practice (Ertmer & Newby, 1993), for example, through workshops prepared by the Palestinian Ministry of Education.

Scientific reasoning was also examined with the teachers' qualifications as the independent variable using a one-way ANOVA. Results revealed a nonsignificant main effect, $F=2.21$, $p=0.16$, for the different qualifications; teachers who had more than a bachelor's degree had the highest total scientific reasoning. The same nonsignificant results were observed for the different qualification subscales. This finding is attributed to the fact that all teachers of primary schools dealt with the same curriculum and participated in the same inservice workshops; this similar professional development may have overcome any differences related to their preservice academic qualifications. The qualification results were compatible with those of Nawawra (2012), Yenice (2011), and An-Najjar (2009).

Differences in scientific reasoning were also examined due to specialization, where *t* tests examined the performances of literary and science specialty teachers. Means for specialization showed differences in teachers' scientific reasoning, where the performance for literary teachers was higher than the mean for science teachers. Nevertheless, the *t* test results showed nonsignificant differences in teachers' scientific reasoning due to specialization. Similar nonsignificant differences were observed for the subscale means for literary and science specialty teachers. Though the imbalance (10 vs. 128) did not allow for fair and meaningful statistical consideration of this variable, the findings were compatible with those reached by Nawawra (2012) and Gha'eb (2011) but not with those of Abu Thoaeb (2005), who found significant difference due to specialization. The present findings are attributed to the fact that all academic courses, whether scientific or literary courses, follow problem-solving strategies and scientific reasoning as tools that serve investigating new scientific and literary phenomena.

## Conclusions and Recommendations

Teachers must create situations where students enact science practices to construct evidence-based arguments to construct their own knowledge and explanation (Berland & Hammer, 2012). The present study shows that these participating teachers integrated scientific reasoning and problem solving at a relatively high level (74.12 %), which indicates the awareness of these science teachers to the importance of science practices to their students' learning. Moreover, the results showed that female teachers practice scientific reasoning more than male teachers. This finding demonstrates that gender roles continue to affect individual decisions on education and careers (European Union, 2011). This influence is represented, for example, in the present study that teaching, as a career in the Khalil District of Palestine, attracts bright women, whereas equal able men are attracted to other careers like engineering.

The highest component performance was for the generalizing phase (89.83 %), while the lowest was for the problem identification phase (63.25 %). This pattern of performance may be caused by the professional learning experience afforded to preservice and inservice teachers that provide pre-identified problems rather than using authentic problem contexts that require the problem solver to identify the specific problem within a complex problem space. Therefore, it is recommended that teacher education courses and workshops should be held at a regular basis, centered on the development of scientific thinking based on problem-solving strategy within ill-structured complex issues that allow a variety of specific problems to be identified and solved. Furthermore, scientific thinking skills programs should be part of the initial preparation program and professional development programs of science teachers. Finally, science textbook authors should take into consideration scientific thinking and problem solving as part of the science curriculum of the primary school and provide learning opportunities and instructional resources to address these critical components of science. Here, too, science textbooks should put emphasis on all the phases of problem-solving strategy.

It is recommended that future research further investigate inservice and preservice science teachers' use of scientific reasoning, as well as problem solving, in their teaching, especially the variance of this use across the different phases of problem solving. It is recommended that qualitative methods be used as observation and interviews to verify additional issues related to scientific reasoning and problem solving in the science classroom. Some of these issues are the preparation state of science preservice teachers regarding the use of scientific reasoning and problem solving in the science classroom, science preservice teachers' perceptions of these constructs as tools that support students' inquiry of scientific phenomena, and inservice teachers' attitudes toward using scientific reasoning and problem solving in their teaching.

## Appendix

Questionnaire (translated from Arabic)

In the Name of Allah the Most Gracious and the Most Merciful
Peace and Mercy of Allah Be on You,
Welcome!

The researcher is conducting a study entitled "Level of Scientific Reasoning of Upper Primary Stage Science Teachers Based on Problem-Solving Methodology." Would you, respondents, please read the following text carefully and answer the questions that follow? The researcher assures you that the information obtained will be treated confidentially and will not be used but for the purposes of scientific research.

Thank you very much for cooperation.

The researcher

**Section One: Personal Information**

**Please answer the following questions by ticking or filling out.**

1- Gender: ( ) Male ( ) Female
2- Years of Experience: ( ) Less than 5 years
( ) 5–10 years
( ) More than 10 years
3- Qualification: ( ) Diploma ( ) Bachelor ( ) MA
4- Specialization: ( ) Scientific ( ) Literary

Section 2: test items

Defining the problem: This section includes (8) paragraphs; each paragraph has a question with three choices. The problems need solutions that reflect the relationship between two variables that can be tested and piloted. Read each paragraph and then choose the question that fits the main problem included in the paragraph:

1. Farmers suffer from a terrible loss due to frost as a result of freezing temperatures that damage their crops in winter. The problem here is …
a. How do farmers avoid the impact of frost on their crops?
b. How do farmers avoid freezing water as a result of low temperatures?
c. How do farmers get rid of frost in winter?
2. One of the challenges facing the spread of computers at schools is the low level of computer knowledge among workers in education. The problem is …
a. What are the challenges facing the spread of computers at schools?
b. What are the causes of low educational computing knowledge?
c. How can we raise the level of computing skills and knowledge?
3. A person belongs to a family suffering from a serious genetic disease that has led to the death of a number of relatives. This person fears dying from this disease. The problem is …
a. How do we eliminate the fear of death with this person?
b. What are the causes of having a genetic disease in the family?
c. How do we treat/face this genetic disease?
4. A residential building has recently fallen down in one neighborhood in a big city. The residents panicked and were displaced. The problem is …
a. What caused the falling down of the building?
b. What caused the residents' panic?
c. How can we avoid other accidents of falling down in the neighborhood?
5. Daily reports point out the prevalence of smoking among school children, which exposes them to facing discipline. The problem is …
a. Why do school children violate school rules?
b. What makes students be punished at schools?
c. How can we help school children get rid of the smoking phenomenon?
6. One security officer claims the spread of drug use among people of one border area. The problem is …
a. How can we avoid the lack of having anti-drug patrols in border areas?
b. What causes the increased rates of drug trafficking in these border areas?
c. How can we eliminate the phenomenon of drug use in border areas?
7. A report of traffic police indicates an increase in traffic accidents due to speed; this results in terrible loss of lives and properties. The problem is …
a. Why are there no strict rules to restrict traffic accidents?
b. What increases the rate of traffic accidents?
c. How can we reduce and limit the rates of traffic accidents?
8. Environmentalists feel frustrated as they notice an increase in pollution despite the large number of awareness campaigns released in media. The problem is …
a. What causes the failure of these awareness campaigns aimed at protecting the environment?
b. How can we reduce the rates of pollution?

c. Why do environmentalists feel frustrated?

Choosing hypotheses: A hypothesis is an educated guess that serves as a possible explanation of an observation. Following are six paragraphs with six situations; each situation is followed by three options. Choose the option that represents the best hypothesis.

9. Among the challenges facing the spread of computers at schools is lack of computing knowledge in educators and workers. A possible hypothesis is …
 a. The spread of computers helps teachers to use them.
 b. The level of computing skills is crucial in education.
 c. The spread of computers helps develop the educational process.
10. Daily reports point out the prevalence of smoking among school children, which exposes them to facing discipline. The main hypothesis is …
 a. School rules help limit and reduce smoking.
 b. Spread of smoking among students leads them to punishment.
 c. Punishment helps students to abide by rules and regulations.
11. One security officer claims there is a spread of drug use among people of one border area. The best hypothesis is …
 a. Acts of border patrols will reduce and limit use of drugs among residents.
 b. Acts of border patrols reduce and limit drug trafficking.
 c. Increase of drugs results in spread of them in border areas.
12. Environmentalists feel frustrated as they notice an increase in pollution despite the large number of awareness campaigns released in media. The hypothesis is …
 a. Awareness campaigns will reduce and limit environmental pollution.
 b. Increase of pollution leads to health problems and hygiene deterioration.
 c. Failure of awareness campaigns lead to frustration.
13. An educational expert states that students suffer from stress and anxiety as examinations approach; this, in turn, affects their achievement. The hypothesis is …
 a. Failure in tests leads students to feel anxious and stressful.
 b. Reducing anxiety among students results in enhancing their achievement in tests.
 c. Tests increase levels of anxiety and stress among some students.
14. A report of traffic police indicates an increase in traffic accidents due to speed; this results in terrible loss of lives and properties. The hypothesis is …
 a. There is an increase in number of accidents.
 b. Lack of strict laws against traffic accidents leads to losses in life and property.
 c. Enacting strict laws against accidents helps reduce and limit them.

Testing hypotheses: this section contains six paragraphs with three choices; each choice represents procedures to test the hypotheses. Choose the best answer.

15. A botanist noticed that plants exposed to sunshine grow while those not exposed wither and die. The hypotheses can be verified by …
 a. Exposing some plants to sunshine and observing their growth.
 b. Exposing a particular plant to sunshine, putting another plant away from sunshine, and watching both.

c. Exposing a number of plants to sunshine, putting another group away from sunshine, and watching the two groups.

16. One security officer claims the spread of drug use among people of one border area. This hypothesis can be verified by comparing the rates of drug use …
   a. Among residents of different border areas.
   b. In one border area and other border areas.
   c. In some border areas and other nonborder areas.
17. A company claimed that it has produced toothpaste that protects against tooth decay. The hypothesis can be tested by observing the effect of the new toothpaste on …
   a. A group of children chosen randomly.
   b. A group of children who do not have tooth decay.
   c. A group of children who have tooth decay.
18. A company claimed to produce a new type of milk (X) for children that helps them grow faster than children feeding on another milk (Y). This claim can be tested through comparing the growth rate of children feeding on X with the growth rate of others who …
   a. Feed on Y milk and are supplemented with natural feeding.
   b. Feed on Y milk without being supplemented with natural feeding.
   c. Feed on X supplemented with Y.
19. A chemical products company claimed to produce a laundry detergent that removes the worst stains from clothes. This claim can be verified and tested by washing some laundry using the new detergent and observing its impact on …
   a. Cleaning some pieces of clothes.
   b. Removing fatty stains from clothes.
   c. Removing stains that cannot be removed by other traditional detergents.
20. A researcher suggests that violent programs on television lead to aggressive behavior by children. This claim can be tested by observing the rate of violence acts in children who watch …
   a. A lot of varied television programs.
   b. Violent television programs.
   c. Violence-free television programs.

Interpretation: This section includes six paragraphs with three explanations for each. Choose the best applicable one.

21. A botanist noticed that plants exposed to sunshine grow while those not exposed wither and die. This phenomenon takes place because …
   a. Sunshine helps plants to grow.
   b. Darkness harms plants.
   c. Sunshine is vital for plants to grow.
22. Fans of the national football team notice a drop in their performance in the middle of the second half; they receive many goals and lose games. This loss can be attributed to …
   a. The many goals the national team gets.
   b. The drop in their performance in the second half.
   c. The drop in their morale.

23. A dentist used a special filling to cure a decayed tooth of one patient, who complained about losing the filling after eating hot food. The best explanation for this phenomenon is …
  a. The patient's teeth are damaged and beyond repair.
  b. Hot foods lead to losing the filling.
  c. The rate of filling extension is higher than teeth extension.
24. Environmentalists feel frustrated as they notice an increase in pollution despite the large number of awareness campaigns released in media. The increase in pollution results from …
  a. The awareness campaigns are futile and useless.
  b. Environmentalists' frustration.
  c. Exploiting the environment.
25. A report from a legal court shows an increase in divorce rates. Such an increase harms children by …
  a. Disintegrating families.
  b. Increasing divorce cases.
  c. Not observing children's rights.
26. An educational expert states that students suffer from stress and anxiety as examinations approach. Such stress and anxiety result from …
  a. Approaching school examinations.
  b. Increasing rates of failure in examinations.
  c. Fearing to fail examinations.

Generalization: This section includes six paragraphs with three statements for each. They represent possible generalizations. Choose the correct answer, which can be inferred from the texts.

27. Reports from a hospital show that 75 % of lung diseases result from smoking; another hospital claims that smoking causes 82 % of lung diseases. It can be inferred that …
  a. Causes of lung diseases cannot be identified.
  b. Smoking is a major cause of lung diseases.
  c. Hospital reports about lung diseases cannot be trusted.
28. A botanist noticed that plants exposed to sunshine grow while those not exposed wither and die. This means that …
  a. Some plants cannot resist environmental change.
  b. Plants' needs of sunshine differ according to their type.
  c. Sunshine is vital for the growth of plants.
29. A famous surgeon carried out a surgery on a patient, who died after some hours. This refers primarily to …
  a. The medical services, in that hospital, are weak.
  b. The surgeon is not competent.
  c. The surgery failed.
30. A residential building in a big city neighborhood had fallen down. This means that …
  a. People should not deal with the constructing company.
  b. The land was not suitable for construction.

c. The building was not constructed properly following scientific, architectural standards.

31. A report from the Center of Seismology shows that it is difficult to predict the occurrence of an earthquake in a particular area as a result of the lack of indicators. This report includes the following generalization …
 a. An earthquake is unlikely to happen in that area.
 b. Predicting when an earthquake will happen is difficult due to lack of capabilities.
 c. It is possible to predict an earthquake depending on some indicators.
32. The results of four educational studies show that students' levels of stress and anxiety increase as physics, chemistry, biology, and mathematics examinations approach. This refers to …
 a. When examinations approach, stress levels increase.
 b. When examinations of scientific materials approach, stress levels increase.
 c. It is impossible to reach a generalization out of the given text.

Answer key

| No. of question item | Answer | No. of question item | Answer |
|---|---|---|---|
| 1 | a | 17 | b |
| 2 | c | 18 | b |
| 3 | a | 19 | c |
| 4 | c | 20 | c |
| 5 | c | 21 | c |
| 6 | b | 22 | b |
| 7 | c | 23 | c |
| 8 | a | 24 | a |
| 9 | a | 25 | a |
| 10 | c | 26 | c |
| 11 | b | 27 | b |
| 12 | a | 28 | c |
| 13 | b | 29 | c |
| 14 | c | 30 | c |
| 15 | c | 31 | b |
| 16 | c | 32 | b |

## References

Abdul Aziz, S. (2007). *Talim At-tafkir wa Asasiyyatoh* [Teaching thinking and its skills]. Amman, Jordan: Dar Al Thaqafa.

Abu Thoaeb, A. (2005). *Ostawa al-Tafkir Al-elmi lada Moallemi Al-marhala Al-asasyya fi* moderyat *Qasabat Al-mafraq* [Level of scientific reasoning of teachers of primary school in Qasabat Al-mafraq] (Unpublished master's thesis). Al-Mafraq, Jordan: Al-albayt University.

Acar, O. (2014). Scientific reasoning, conceptual knowledge, & achievement differences between prospective science teachers having a consistent misconception and those having a scientific conception in an argumentation-based guided inquiry course. *Learning and Individual Differences, 30*, 148–154. doi:10.1016/j.lindif.2013.12.002.

Al-Haddabi, D., Al-Folfili, S. & Al-olaibi, T. (2011). Mostawa Maharat At-tafkir Al-ibda'e lada At-talaba al-moallimin fi Al-aqsaam Al-ilmiyya fi Kolliyat At-tarbiyya wa Al-oloom At-tatbiqiyya [Level of creative thinking skills of science student teachers in scientific departments at the Faculty of Education]. *The Arab Journal of Talent, 2*(3), 34–57.

Al-Jobaili, A. (2013). Al-forooq Al-ma'rifyya bayna Talabat Jameat Al-imam Mohammad in So'od Al-islamyya fi Mostawa maharaat hal Al-moshkila [Knowledge differences among students of Imam Muhammad bin Saud Islamic University in terms of level skills of problem solving]. *Journal of Al-Oloom Al-insanyya wa Al-Ijtima'a, 29*, 74–112.

Al-Masaeed, A. (2011). At-tafkir Al-ilmi enda talabat Al-Jameah wa Alaqateh be Al-kafa'a Al-thatiyya Al-aamah fi Dawi ba'ad Al-motaghiraat [Relationship of scientific thinking skills with general self-efficiency for the student according to some variables]. *Journal of Islamic University, 19*(1), 679–707.

American Association for the Advancement of Science (1993). *Benchmarks for science literacy: Project 2061*. New York, NY: Oxford University Press.

An-Najjar, H. (2009). *Mostawa Al-qodra ala Hal Al-moshkila lada Moalimi wa Moalimat Thawi Soobat Al-tallom fi Madinat Jeddah* [Level of teachers', with learning disabilities, ability to solve problems in the city of Jeddah]. *Journal of Psychological and Educational Research, 2*, 127–148.

An-Nimer, M. (2003). *At-tafkir Al-ilmi wa At-tafkir An-naqdi in Bothoth Al-Khidma Al-ijtimaiyya* [Scientific reasoning and critical thinking in the field of social service]. Alexandria, Egypt: Modern University.

Berland, L. K. & Hammer, D. (2012). Framing for scientific argumentation. *Journal of Research in Science Teaching, 49*(1), 68–94.

Chen, C.-T. & She, H.-C. (2015). The effectiveness of scientific inquiry with/without integration of scientific reasoning. *International Journal of Science and Mathematics Education, 13*(1), 1–20.

Coletta, V. P. & Philips, J. A. (2005). Interpreting FCI scores: Normalized gain, preinstruction scores, and scientific reasoning ability. *American Journal of Physics, 73*(12), 1172–1182.

Ediger, M. (2013). Science and the common core state standards. *Virginia Journal of Science Education, 5*(1), 8–33.

Ertmer, P. A. & Newby, T. J. (1993). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly, 6*(40), 50–72.

European Union (2011). *Strategy for equality between women and men 2010–2015*. Luxembourg: Publications Office of the European Union.

Gaio, D. C., Moyses, S. J., Besinelli, J. C., Franca, B. H. & Moyses, S. T. (2010). Health promoting schools and their impact on the oral health of mentally disabled people in Brazil. *Health Promotion International, 25*(4), 452–434.

Gallagher, S. A. (1997). Problem-based learning: where did it come from, what does it do, and where is it going? *Journal for the Education of the Gifted, 20*(4), 332–362.

Gertzman, A. & Kolodner, J. L. (1996). *A case study of problem-based learning in a middle-school science class: Lessons learned. Proceedings of ICLS '96*. Charlottesville: AACE.

Gha'eb, N. (2011). Istratijiyyat hal Al-moshkila lada Talabat Al-marhala Al-iedadiyya fiQadaa Khanqin [Problem-solving strategies of middle school students in the district of Khanqin]. *Journal of Research Diyala Humanities, 52*, 669–705.

Harithy, E. (2000). *Teaching science using problem solving strategy: Theory and practice*. Riyad: Al-shaqri for Publishing and Distribution.

Huang, T.-Y., Wu, H.-L., She, H.-C. & Lin, Y.-R. (2014). Enhancing students' NOS views and science knowledge using Facebook-based scientific news. *Educational Technology & Society, 17*(4), 298–301.

Kuhn, D. (2002). What is scientific thinking and how does it develop? In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 371–393). Oxford, England: Blackwell.

Kuhn, D. & Franklin, S. (2006). The second decade: What develops (and how). In W. Damon, R. M. Lerner, D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology* (Cognition, perception and language 6th ed., Vol. 2, pp. 953–993). Hoboken, NJ: Wiley.

Mayer, D., Sodian, B., Koerber, S. & Schwippert, K. (2014). Scientific reasoning in elementary school children: Assessment and relations with cognitive abilities. *Learning and Instruction, 29*(February), 43–55. doi:10.1016/j.learninstruc.2013.07.005.

Morris, B. J., Croker, S., Masnick, A. & Zimmerman, C. (2012). The emergence of scientific reasoning. In H. Kloos, B. J. Morris & J. Amaral (Eds.), *Trends in cognitive development* (pp. 61–82). Rijeka, Croatia: InTech.

Nashwan, Y. (2005). *At-tafkir Al-ilmi wa At-tarbiya Al-amaliyya* [Scientific reasoning and practical process]. Amman, Jordan: Dar Al-Forqan.

National Research Council (1996). *The national science education standards*. Washington, DC: National Academies Press.

National Research Council (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. H. Quinn, H. A. Schweingruber & T. Keller (Eds.). Washington, DC: National Academies Press.

Nawawra, S. (2012). *At-tafkir Al-ilmi lada Moallimi Al-marhala Al-asasiyya al-Olya fi Mohafathat Bayt Lahem* [Scientific reasoning of upper primary school teachers in Bethlehem Governorate] (Unpublished master's thesis). Al-Quds University, Al-Quds, Palestine.

Osborne, J. (2013). The 21st century challenge for science education: Assessing scientific reasoning. *Thinking Skills and Creativity, 10*, 265–279.

Palestinian Curriculum Development Center (2014). *School books 5–10.* Ramallah, Palestine: Author. Retrieved from http://www.pcdc.edu.ps/ar/index.php?p=textbooks2 [in Arabic].

Ross, K., Lakin, L. & Callaghan, P. (2004). *Teaching secondary science* ($2^{nd}$ ed.). London, England: David Fulton.

Scherera, R. & Tiemann, R. (2014). Evidence on the effects of task interactivity and grade level on thinking skills involved in complex problem solving. *Thinking Skills and Creativity, 11*, 48–64.

Tajudin, N. M., Saad, N., Rahman, N. A., Yahaya, A., Alimon, H., Dollah, M. U. & Abd Karim, M. M. (2012). Mapping the level of scientific reasoning skills to instructional methodologies among Malaysian sciences, mathematics and engineering undergraduates. *International Journal of Humanities and Social Science, 2*(3), 147–153.

Tümkaya, S., Aybek, B. & Aldağ, H. (2009). An investigation of university students' critical thinking disposition and perceived problem solving skills. *Eurasian Journal of Educational Research, 36*, 57–74.

Wilkening, F. & Sodian, B. (2005). Scientific reasoning in young children: Introduction. *Swiss Journal of Psychology, 64*(3), 137–139.

Yenice, N. (2011). Investigating pre-service science teachers' critical thinking dispositions and problem solving skills in terms of different variables. *Educational Research and Reviews, 6*(6), 497–508.

Yu, K-C., Fan, S-C. & Lin, K-Y. (2014). Enhancing students' problem-solving skills through context-based learning. *International Journal of Science and Mathematics Education*. Advance online publication. doi: 10.1007/s10763-014-9567-4.

Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. *Developmental Review, 27*(2), 172–223.