Bulgarian Chemical Communications, Volume 50, Special Issue B, (pp. 72 – 74) 2018

Cognitive problems for developing students' scientific literacy in their physics education

R. I. Vassileva

Department of Physics, Faculty of Mathematics and Natural Sciences, South-West University,66, Ivan Mihailov Str., 2700 Blagoevgrad, Bulgaria

Received: July 12, 2017; Revised: October 24, 2017

The paper deals with one of the most topical issues related to school education – how to form and develop key competencies in natural sciences? A variety of strategies for the realization of this goal are explored and a focus is placed on the opportunities to solve context-based real-life problems. The author suggests custom-designed problems which can be used in physics education. They are in agreement with the requirements of the Program for International Student Assessment (PISA).

Keywords: Science education, Scientific literacy, Key competences, Context-based real-life problems, PISA

INTRODUCTION

The acquisition of scientific literacy appears to be a main contemporary tendency in natural sciences education in the compulsory stage of school education. PISA defines scientific literacy as the ability of the student to engage conscientiously with natural sciences-related issues and thus to demonstrate:

- „Scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues.
- Understanding of the characteristic features of science as a form of human knowledge and enquiry.
- Awareness of how science and technology shape our material, intellectual and cultural environments.
- Willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen."[1].

This definition is from 2006, when the research of PISA had put the accent on natural sciences for the first time. The concept of scientific literacy assessment was further developed and broadened in the following detailed research in 2015. Which are the main elements of scientific literacy under PISA 2015?

1. *Three basic science-related competences* accentuating the scientific approach to knowledge acquisition:
   - Explaining scientifically natural processes and phenomena;
   - Designing and evaluating scientific enquiry;
   - Interpreting scientifically data and evidence.
2. *Context:* PISA assesses the ability of the students to apply the acquired competencies in *real-life context* using scientific and technological knowledge and skills.
3. *Attitudes:* PISA assesses students' attitudes by studying their interest in natural sciences and technologies, their understanding of the scientific approach and their responsible attitude to the environment.
4. *Knowledge:*
   - *Content knowledge* (an understanding of the major facts, concepts and explanatory theories that form the basis of scientific knowledge of both the natural world and technological artefacts).

In terms of content, the knowledge assessed by PISA is grouped in three areas: physical systems (structure and properties of substances, chemical changes in substances, movement and strength, energy and energy transformation, interconnection between energy and matter); biological systems (cell, human, population, ecosystem, biosphere); Earth and Space (structure of the Earth, energy and energy resources).

- *Knowledge about science**:***
- *Procedural knowledge* (knowledge of the procedures, methods and means used in the scientific research)
- *Epistemic knowledge* (understanding of the underlying rationale for these procedures and the justification for their use) [2, 3].

It is clear that what is defining for the contemporary natural sciences education is not only the subject matter that is going to be acquired in class and what the students must know, but also the skills, values and attitudes that must be formed. This is of paramount importance for the more flexible adaptation of the young people to their environment

* To whom all correspondence should be sent.
E-mail: radostiv@abv.bg

and it is an essential factor for their full personal and professional realization in life. Therefore, solving the problem of the students' scientific literacy requires the use of the competence approach in organizing and putting into practice the natural sciences education.

The education practice has demonstrated a number of strategies for the development of key natural sciences competencies:

- Project-based learning
- Inquiry-based learning
- Hands-on activities
- Extracurricular activities – competitions, festivals, natural sciences olympiads, etc.
- Solving context-based real-life problems.

The present paper focuses on the last of the strategies above. A few cognitive tasks (type PISA) are offered, which have been created by the author specifically for physics education. They demand from the students to apply already acquired knowledge in new conditions – in the context of real-life situations.

EXEMPLARY COGNITIVE TASKS IN REAL-LIFE CONTEXT

Science example: Solar cooking

Text 1

According to the World Meteorological Organization, the total radiant energy received from the Sun at the upper limit of the atmosphere per unit of time per unit of area on a surface perpendicular to the Sun's rays is $1367\,\mathrm{W/m^2}$. It is called *solar constant* and it is the approximate average value of solar intensity for one year. Due to the movement of the Earth around the Sun in an elliptical orbit, the real solar intensity varies with $\pm 3\%$ of the value of the solar constant. Its maximal value is $1420\,\mathrm{W/m^2}$, when the Earth is closest to the Sun (perihelion of the Earth's orbit around the Sun), and its minimal value – $1325\,\mathrm{W/m^2}$, when the Earth is farthest from the Sun (aphelion).The solar constant determines the amount of direct solar radiation (DSR) that reaches the Earth's orbit. What amount of DSR will fall on a specific place of the Earth's surface, however, depends on a number of factors. One of them is the physical state of the atmosphere above the place.

Task 1: Point out which of the following process/es in the Earth's atmosphere cause/s weakening of the solar intensity:

- o The absorption of part of the solar radiation by the atmospheric gases.
- o The diffusing of part of the solar radiation by the air molecules and by the solid and liquid impurities (aerosols) in the air.
- o The reflecting of part of the solar radiation by clouds in the atmosphere.
- o All the processes above cause weakening of the solar intensity.

Science example: Solar cooking

Text 2

The DSR reaching the Earth's surface is of practical significance for the functioning of the so-called solar cooking appliances. Fig. 1 shows a solar parabolic cooker (SPC) with a diameter of the reflector $D = 150$ cm.

The reflector has the form of a paraboloid and is covered with reflective foil, the purpose of which is to reflect the solar radiation falling on it with the highest possible reflection coefficient.

Fig. 1. Solar parabolic cooker.

The foil on the solar cookers has a normal reflection coefficient R of 90%. Every SPC is actually a parabolic mirror. The solar rays parallel to the axis of the reflector reflect in it, after which they pass through the focus (Fig. 2).

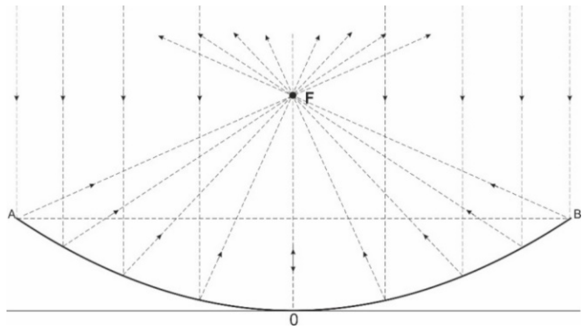

Fig. 2. Principle of action of the solar parabolic cooker (mirror): AB – diameter of the reflector; OF – focal distance.

Practically, the focus of SPC is a focal spot of small size, and it is not a point in the geometric sense of the word. A metal container (a saucepan, a pan), put in the area of focus absorbs the radiant energy concentrated there, it is heated to a great degree and thus the process of cooking in the container is performed. The power of the SPC is determined by the formula

$$P = ES, \qquad (1)$$

where E is the solar intensity and S is the area of the mirror opening (called aperture).

Task 2: Calculate the heating time of $1\ \mathrm{kg}$ of water at $20\ ℃$ to $100\ ℃$ with the solar cooker on Fig. 1, if you know that the solar intensity is $800\ \mathrm{W/m^2}$ (we consider it constant for a period of time), and the container that holds the water absorbs $85\ \%$ of the radiant energy reflected in the parabolic mirror.

Science example: Solar cooking

Text 3

The maximal power of a given solar cooker for a particular location and day of the year is reached if the following three conditions are fulfilled simultaneously:

- Clear and dry weather;
- The Sun is in its climax, which is at noon;
- The mirror is positioned with its axis parallel to the coming Sun’s rays.

Task 3: Explain the role of each of the mentioned conditions to reach to maximal power of the solar cooker.

Science example: Solar cooking

Text 4

The use of the solar cooker is most effective during those days of the year in which the Sun is highest above the horizon. In this case, the path of the Sun's rays through the atmosphere is the shortest and the weakening of the direct solar radiation is the least. The maximal height h of the Sun for the day is determined by the formula:

$$h = 90^\circ - \varphi + \delta, \qquad (2)$$

where φ is the latitude, δ is the Sun’s declination (the angle below which the Sun's rays cross the plane of the Earth’s equator – Fig. 3).

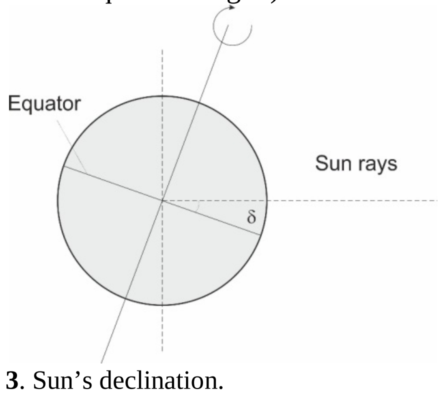

Fig. 3. Sun’s declination.

As it is known, the values of the declination δ vary from $+23^\circ 27'$ (during the summer solstice on June 22) to $-23^\circ 27'$ (during the winter solstice on December 22). The value of the declination is zero during the equinoxes.

Task 4: Use formula (2) and make a rough assessment of the potential possibilities of solar cooking in the following three countries: Germany, Bulgaria and Sweden considering the fact that the latitude of Germany is between 47 and 55° N, the latitude of Bulgaria – between 41 and 44° N and the latitude of Sweden – between 55 and 69° N.

Science example: Solar cooking

Task 5: Describe two advantages and two disadvantages of the SPCs.

It is important to mention that the effectiveness of using such type of tasks in the educational process can be enhanced if they are combined with elements from other strategies for forming key natural sciences competencies. In this particular case, demonstrations of cooking with the SPC from Fig. 2 were made for students from Blagoevgrad, as an extracurricular activity. Task 2 was tested experimentally. The necessary time for heating the water happened to be longer than it had been estimated theoretically. This provoked a discussion regarding the possible reasons for this result. A solar oven with a principle of action that is different from that of the SPC was also demonstrated.

CONCLUSIONS

The creation and use of real-life context tasks is not a novelty in physics education, however, such approach is particularly relevant regarding scientific literacy. The students are supposed to apply the acquired interdisciplinary knowledge and skills in real-life situations as they are searching for proof, drawing conclusions, providing arguments for their answers and making decisions. Thus they are convinced in the benefit of what is studied and develop very important skills – to find, analyze, transform and present various types of information. Therefore, the education helps the personal development of the students and this inevitably increases their motivation and interest in studying natural sciences.

REFERENCES

1. OECD, PISA 2006 Science Competencies for Tomorrow’s World, Volume 1: Analysis, OECD Publishing, p. 34, 2007.
2. OECD, PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematics and Financial Literacy, OECD Publishing, Paris, 2016.
3. Ministry of Education and Science of Bulgaria, Natural sciences and technologies in school of the XXI century, Center for Control and Assessment of the Quality of School Education, Sofia, 2016.