RELATIVE MOLECULAR MASS AND RELATIONSHIP TO OTHER NATURAL SCIENCES

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Abstract

The report presents a learning activity conducted in chemistry and environmental science classes. A high degree of inter- and transdisciplinary was achieved during its implementation. Relative atomic and molecular mass and their relationship to other natural sciences are discussed. A variety of teaching approaches and methods are applied, some of which are: exploratory approach, experiential learning, learning by doing, small group work, etc. During the activities, various electronic applications are used, models of molecules are constructed, and a variety of problems are posed and solved. One of the final products of the lesson is related to the students' creative activity in constructing a model of a cave.

Keywords: *relative molecular mass, chemistry, model, STEAM, science literacy*

1. INTRODUCTION

The rapid development of science and technology, the ongoing educational reform, as well as the regulatory changes are a challenge for every teacher, as the main task for science teachers is to form students' science literacy properly. The evolution of views, ideas, propositions about literacy and their re-evaluation in the light of the new socio-cultural context gives grounds to draw a conclusion about the complex-integral character of functional literacy. The interrelated constituents of functional literacy include literacy in science.

In science teaching, the application of the Science, Technology, Engineering and Mathematics (STEM) approach to learning has been particularly effective. Teaching based on this approach is associated with innovativeness in teachers' teaching, which is directly oriented to learners. The inclusion of art as part of this type of learning is a prerequisite for the development of students' creativity. Its application requires teachers to plan activities and organize their work so that learning is practical and transdisciplinary-oriented. This requires learners to make quick cross-curricular connections when solving given cases and problems. Currently, science curricula are not structured in the direction of Science, Technology, Engineering, Arts and Mathematics (STEAM)-based learning. For this reason, it is the pedagogical skill of the teachers that is of particular importance in order to create a lesson in regular classes in compulsory education through this approach. It is likely that once the conditions have been created through established STEM centres, changes will be made to the curriculum, but at present this is a teacher or school level decision especially where the teaching team is working on STEAM.

This will certainly be a major task for the expert groups whose focus is science curricula. It would be one of the new and major trends in education, which would be an introduction of innovation in the learning process and help in the formation of science literacy. The particular relevance is when this is applied in formal education in regular science classes. The application of STEAM-based learning is also related to the proper selection of media, which would be achieved very effectively if accurate targeting and clear structuring of learning content is done. Goal-setting is of particular importance as this is the basis for selecting appropriate methods and approaches to achieve them. Clearly structuring the learning content into topics and sections is a major task for every teacher. When selecting methods, tools and approaches, it is important to take into account both the age characteristics of the pupils and their cognitive level.

An integral part of the learning process in natural sciences are experimental activities, as well, as creative tasks that provoke thinking based on experience. The inclusion of such tasks when introducing new

knowledge is particularly important. This leads to a new, practically oriented learning, while at the same time it is emotionally intense and would be applied "in problem solving and decision making in different life situations related to science and technology" [1].

This empathy in guiding the learning process is a motivational aspect of science education by creating conditions to "attract and maintain a high level of emotion and attention"[2], stimulating students to actively participate in the lesson components, building emotionally meaningful relationships, choice, satisfaction from creative and experimental work and the results achieved.

The proposed activity is an alternative option for the implementation of some of the creative tasks that are in accordance with the specific pedagogical conditions, resources, psychological characteristics and motivational status of the student's personality. They are a motivational tool to increase the effectiveness and efficiency of the learning process in formal education with optimal integration in certain pedagogical situations. The described activities enrich the teacher's pedagogical toolkit. Thus, on the one hand, his methodological competence is increased and, on the other hand, the motivation and desire for development of students is increased. The linking of the compulsory training in natural sciences with the construction of a model or a model connected with the study of complete objects of the surrounding reality creates conditions for making sense of the application of knowledge in real life. The work on the creation of a model or a prototype is a prerequisite for the learners to understand the power of independent learning, curiosity, generation of ideas, detailing them, forming natural science literacy and making sense of the relationship between sciences.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in the course of the lesson and the planned activities are divided into:

- didactic: chemistry textbook, workbook- and worksheets with tasks. They support the perception of new knowledge, work with the Periodic Table of chemical elements, as well as solving different types of tasks requiring the transfer of knowledge towards the development of skills.

- electronic resources: learning apps, live worksheet, QR code creator and tablets. They are used in the implementation of activities related to the individual components of the lesson – in the updating of knowledge, the actual activities in the perception of the concept of relative molecular mass and solving problems with it.

- resources for modelling: Styrofoam, paints, glue, LED tape, black cardboard, black cardboard marker, chiffon fabric, modelling kits and others that are related to the creation of models and prototypes.

2.2.Methods

Regardless of the methods used to increase learner motivation in STEAM-based learning, the environment in which the learning process will take place is important. It should stimulate creativity and critical thinking in order to enable students to move through the cognitive process and successfully grasp the essence of the topic being addressed and the cross-curricular connections. Interactive methods such as lecture, teamwork, case studies, etc. are used in the class to increase students' engagement in collaborative and team learning related to experiential learning. Particularly useful is the hands-on learning-by-doing method, through which learners' creativity is developed as they apply their skills to produce a final product on the topic – in this case a model cave. In some of the tasks the inquiry method is applied, encouraging logical thinking where knowledge is put into practice and skills are formed.

Everything that is included in the activity is related to the application of one of the emotional methods – experiential learning – which can be defined as learning from experience achieved by putting into practice conclusions drawn as a result of training. The application of this method provokes responsible behaviour in students and stimulates their thinking in order to generate ideas. Although this method was developed by the American philosopher John Dewey at the beginning of the 20th century, it is increasingly being applied and the results of its application are proving its effectiveness. The application

of this method is directly related to the exploratory approach associated with the search method through which students solve a problem related to the discovery in the shortest time of the oldest caves in our country.

The team approach in the students' work brings them closer to the demands of modern society, appears to be a natural support of discovery learning and puts them in a situation to suggest ideas in teaching and implementing the learning content, thus helping to form attitudes to learning and applying knowledge and forming skills.

Other methods that were used in the course were: flipped classroom, modeling method, brainstorming, discussion, lecture, etc. The point related to the course of the lesson further describes the place of application of these methods.

2.2.1. Course of the lesson

The class described was conducted during two regular chemistry and environmental science classes. In the course of its implementation, a high degree of inter- and transdisciplinarity was achieved, which corresponds with the STEAM concept. The implementation of such lessons is of particular importance, as it enables each child to discover his/her strength or to provoke an interest in a particular science and subsequent career development.

It starts with a heuristic talk on atoms, molecules and ions. The particles of matter are dealt with on an empirical level already in the subject Man and Nature in the sixth grade[3]. In part II of the curriculum Substances and their properties, some of the competences expected as a result of the students' learning are: they describe the basic building blocks of substances: atoms, molecules and ions; distinguish atoms, molecules and ions by their characteristics; to define a chemical element as atoms and ions with the same number of protons in the nucleus, etc. [3].

These competencies are built upon in 7th grade Chemistry and Environmental Science [4] in the Chemical Symbolism section on Relative Atomic Mass and Relative Molecular Mass. The topic is strictly specific to the science area of chemistry and environmental protection. Of particular importance here is the approach to be taken to introduce the topic, as well as the pedagogical skill of the teacher. The magnitude of the relative molecular mass is of particular relevance to stoichiometric problems in chemistry as it relates to the solution of quantitative problems from 8th to 12th grade. It is important to note that the relative molecular mass of any substance can be calculated irrespective of its field of application. This applies to many fields such as physics and astronomy, biology, geography, engineering sciences, etc.

In the natural sciences, this quantity is of particular importance, which is why it is useful in this topic to make connections with other natural sciences through problems, practical examples, modelling and other methods and approaches. In this way the integral approach, which is not new to education, is applied. It has historical roots, but its general principles can be integrated into the natural sciences in order to ensure systematisation, interdependence and of course transdisciplinarity between them.

The integrative relationship between chemistry, physics, biology, technology, fine arts, geography and mathematics is fundamental and is part of the mixed and multi-layered model of constructivism. The focus of this paper is the horizontal inter-relation between these sciences.

According to M. Andreev, the systems approach "is often used to justify integration processes in education" [5], because integration is a synthetic construction of a whole from parts, integrating different academic subjects and unifying them, which it considers in different multilayered aspects.

It is important to note that integration in learning is a basic necessity for all subjects, although it is more appropriate for only some of them. Integration activities should be of a problem-oriented nature that is subordinate to the subject content. It makes the transition from theory to practice and provokes productive thinking. The integration links in the lesson are described in the report presenting the lesson on 'Relative atomic mass and relative molecular mass'. The study of the topic of relative molecular mass is present in the state educational standard as an area of competence, expanded and deepened in the content of the expected outcomes of knowledge, skills and relationships between the two stages of junior

and senior high school. While in the lower secondary stage the conceptual knowledge is achieved by means of a description of the quantity, the same is already extended and deepened in the upper secondary stage as a relation to molar mass, molar volume, molar concentration [7].

After the heuristic talk at the beginning of the session, an inter-relationship with the science of physics follows through the Big Bang theory and the derivation of particles appearing in the first microseconds. The three main structural levels are outlined in scientific terms: the microworld, the macroworld and the megaworld, pointing out that everything related to the building blocks of matter is part of the microworld. Students are divided into four groups: Physicists, Chemists, Biologists and Engineers. Through teamwork and an interesting way of formulating a problem, a knowledge update component is conducted. The task involved inferring the characteristics of the two electroneutral particles atom and molecule and creating models of the atoms of the elements hydrogen, oxygen, carbon and the molecules of oxygen, ozone, carbon dioxide, water, ammonia. In representing the simple substances of carbon, diamond, graphite, and fullerene were to be differentiated. Students used Styrofoam, paints, glue and other materials available at their workstations to create their models. The work time was 3 minutes. This was followed by the creation of posters as a representative from each group placed the group's response, a characteristic feature or pattern, in the appropriate place according to certain attributes. Presentation of the posters followed (Fig. 1).

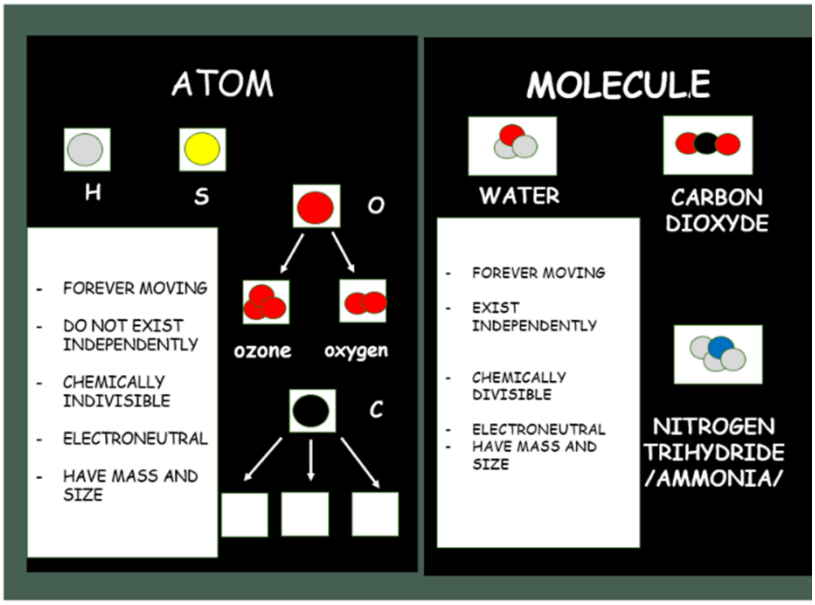

Fig. 1 Posters created by the groups during the knowledge update.

A discussion followed on the characteristics of the building blocks atom and molecule, looking for common characteristics between them. The result of the discussion was the introduction of the topic of the lesson: "Relative molecular mass and its relation to other natural sciences".

Using a specific example of an element from the Periodic Table, the location of the value of relative atomic mass is identified for students to use in calculating relative molecular mass. A 3D cell model of the element sodium is used. A problem created in learning apps and live worksheet looks for a correlation between the relative atomic mass value and the chemical element using the Periodic Table of Elements. This is feedback on the students' knowledge level on the topic.

The next point was related to the presentation of different substances with application in the natural sciences physics, biology, geography, etc. Regardless of the difference in composition and structure of the substances, the relative molecular mass was to be calculated for each of them using the relative atomic mass values. This task challenged students to make the connection between qualitative and

quantitative composition of substances and how to use relative atomic mass to calculate the molecular mass of substances. The students solved the problem by using interdisciplinary mathematics to logically connect a similar type of problem in that science. The solution was presented by the first student who gave the correct answer. Using the flipped classroom method, students had three minutes to ask their teacher any questions that arose during the problem-solving process.

A suitable method for conducting the learning was modelling, which involved creating a model of a molecule of the substance for which they received a description via a QR code. This was followed by the groups calculating their relative molecular mass and an exploratory activity related to the priory for the substance that is present in the area that is associated with the group name. The presentation of the solution of the problem, the model created and the application in the area associated with the group was of interest, as two of the groups were able to create a didactic map in the short time they had.

Problems were posed with the variation of their solution by some relative molecular mass of the substances. This led to the exhaustivity of the problems by searching for an unknown element, the number of atoms of a chemical element in a chemical compound.

This was followed by a task combining the work of the four groups, due to the fact that students should make sense of the fact that they may work in separate teams, but the final product is one and it is the result of combining their solutions. An example of which are large enterprises in which there are separate departments, but the common concept for their development and success is their unity of ideas and solutions.

The global task that connected the four groups was to create the formula of the substance calcium dihydrogen carbonate and for this purpose the students used the value of the relative molecular mass. The formula of the substance was written as A(HVOx)y. To find which was the unknown substance the students used coloured boxes according to the main colour of the sciences whose names the groups bore. In them, students found a problem in which they looked for an unknown element in a compound or an unknown number of atoms of a chemical element. In a time of five minutes, the students put their answers in the appropriate places and found the unknown substance. The problems were related to the substances: methane – chemistry group (they had to find the element B from the formula – C (carbon)), water – biology group (they had to find the index y – 2), dicalcium carbonate – physics group (they had to find the index x – 3), potassium sulphate – engineers group (they had to find the element A from the formula – Ca (calcium)). On solving the problem correctly, the students got information about the substance they had discovered and its application in various natural sciences.

Attention was drawn to some of the most interesting and challenging objects – the caves and the formations in them stalactites, stalagmites and stalactons. This was followed by a discussion on the main characteristics of each cave. An exploratory activity based on the search method was assigned to find the five oldest caves in Bulgaria. To develop the creativity of the students, they were given a creative task related to the creation of a model of a cave with some of the materials they used, making the necessary calculations, measurements. This emotional task further united the four groups, who quickly divided up the parts of the cave they should create so that the final result could be obtained after their assembly (Fig. 2).

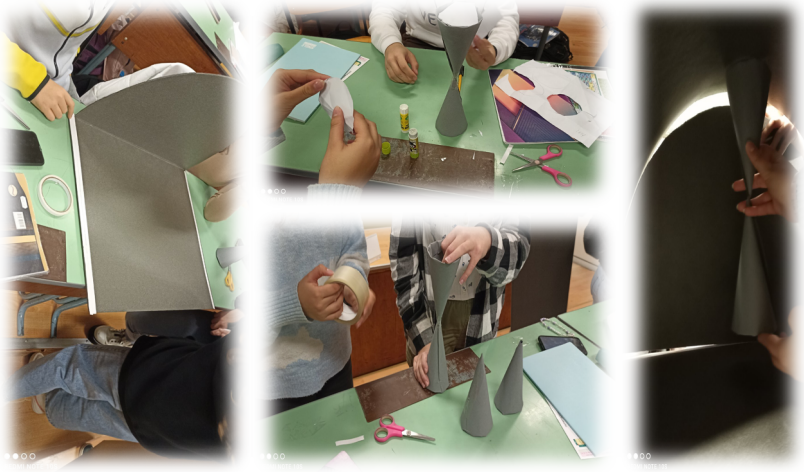

Fig. 2 Working moments related to the creation of a cave model.

3. RESULTS

The learning outcomes based on the STEAM approach help to overcome the learners' traditional perception that a subject's relation to other cultural and educational areas is already taken into account. Pupils understand that science is a unified whole, they successfully record in chemical notation the elements they have studied, and they correctly record the chemical formulae of familiar substances by name.

The results directly correspond to the objectives of the lesson development:

- Integration of chemistry and environmental protection content in the educational process by applying a multidisciplinary, interdisciplinary, transdisciplinary approach;

- acquired skills and competences to apply what has been learned in a new context of a practical and applied nature;

- formed teachings on working with the Periodic table and looking for connections with other natural sciences;

- applied knowledge, developed competencies and engineering skills in the creation of models and prototypes;

- created didactic maps;

- calculate relative molecular mass from a formula of a substance;

- solving problems involving finding an unknown element and number of atoms by a known value of relative molecular mass;

- skills to solve cases with a common end goal;

- developed skills in investigating, analyzing, synthesizing, and summarizing information;

- development of creativity.

Creativity is an expression of man's natural tendency to be active towards his environment and has a strong impact on all areas of the personality. Its educational significance has to do with the formation of a system of knowledge, skills attitudes, competencies. At the cognitive level it contributes to understanding the nature of processes and phenomena. Intellectual, ecological, aesthetic, intercultural education is carried out. It stimulates cognitive independence and activity, develops creative abilities, specific scientific and linguistic culture, motivation, interest in natural sciences.

The activity was attended by teachers from the town of. Yambol and the town of Polski Trambesh, participants of the National Programme "Innovation in Action". The discussions, the tasks presented to the students in different forms and the conditions of the tasks transformed the lesson unit into a multilayered one – Bulgarian language and literature, chemistry, physics, biology, geography, mathematics, information technology, fine arts, technology and entrepreneurship.

The great interest of the teachers present at the session was related to the variety of methods, approaches, tasks and the transformation of a topic that is mainly theoretical into a fully creative one within two hours.

4. DISCUSSION

Of the discussion methods, talk, discussion, brainstorming, discussion are used. Right from the beginning in the initial discussing of the characteristics of the building blocks atom and molecule, looking for common characteristic found applications discussion. As a result of its application, a smooth transition takes place in the setting of the lesson topic: 'Relative molecular mass and its relation to other natural sciences'.

In the course of the lesson itself, talk, discussion, and brainstorming are used consistently in setting and solving versions of relative molecular mass problems. This concludes with a discussion of the creative task of creating a model of a cave and searching for its main features. The result is a research activity based on the search method to discover the five most visited caves in Bulgaria. All the activities carried out during the lesson were discussed with science teachers from Lovech and Polski Trambesh who were present at the lesson.

5. CONCLUSIONS

The application of the integrative approach is particularly effective in forming science literacy. For its fuller application it requires non-traditional thinking and the use of interactive methods, modern educational technologies, developing communication and information transfer skills between several subjects, as well as working with different sources of information, stimulating students' independent and research activities [6]. This further motivates students to search, find and apply information related to the topic at hand. The provoked interest in the subject stimulates logical and creative thinking as well as develops skills and builds a positive attitude towards the learning process. The integration between the sciences included in the lesson facilitates the transfer and acquisition of students' knowledge, skills and competences.

The implementation of such lessons is a prerequisite for the organisation and implementation of future person-centred science projects involving interdisciplinarity. This is particularly important for students who have the opportunity to participate in national and international forums requiring critical thinking in practical problem solving as well as creativity. In recent years, the format of some of the science competitions for the lower-secondary stage have included just such tasks. By participating in such activities, students develop their skills in analysing the information provided, as well as their data selection skills on specific topics related to carrying out creative and experimental activities. The variety of tasks on the subject related to the educational content under consideration, the methods and approaches used for their implementation provoke their cognitive motivation and turn the lesson into an emotional experience.

STEAM-based classes create the conditions for a more effective learning process, which is linked to a meaningful dialogue, collaboration and partnership between participants in the learning process. For students, creative activity is an opportunity to tap into natural knowledge, and for teachers it is a challenging and invaluable experience.

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