STEAM-BASED LEARNING ON "NATURAL COLOR AND COLOR PERCEPTION"

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Abstract

This paper presents a lesson on "Natural Color and Color Perception" in a STEAM-based learning environment. In the course of the described pedagogical practice are touched upon different areas of knowledge in: chemistry, physics, biology, technology, information technology, mathematics, history, etc. The relationship between formal and informal education as a prerequisite for the formation of science literacy is examined. It is shown the possibility of a learning experiment to be used in the educational process. A variety of activities used to stimulate critical thinking and create a working model through color filters are described.

Keywords: *science, STEAM-based learning, color filters, creativity*

1. INTRODUCTION

Of particular interest for educational practice are the problems related to human abilities, methods, means and environment for their development. It is clear to science that man inherits biologically determined aptitudes, which develop as abilities after certain purposeful activities are performed. They are varied and depend on a knowledge, skills and habits, needs and interests, feelings and emotions, will and character, and value system of the human. Through this each ability is a subjective combination of biological endowments and qualities acquired in the process of training and education. Although abilities are primarily studied by the science of psychology, oriented to the characteristics of personality they are also important for pedagogy. According to the Czech educator Jan Amos Comenius, the development of a person depends on three qualities: intelligence, curiosity and amenability to education. Depending on the degree and manner of their combination, for each individual pupil the appropriate measures should be taken and approaches undertaken, even individual ones, to develop his creative abilities. The presence of aptitude does not solve the problem of the development and expression of the abilities.

Even the most pronounced aptitudes cannot develop into abilities if the subject does not practice the corresponding activity. In other words, in order for certain abilities to manifest themselves in a particular field or type of activity, further inclination and interest are necessary, expressed in the preference, desire, and will of the individual one to engage in that activity. This applies to the natural sciences as well. All this should be tailored to the age of the pupils in this case the students who are in 7th grade.

One of the main questions facing science teachers is how to get children interested in these subjects, and how to teach them to put theoretical knowledge into practice. These and many other questions are addressed to the STEM education, which is not a curriculum, but such curriculum-based learning enables teachers to organize their work in a different way in order to help their students to put the pupil's knowledge into practice when they are given a task. STEM learning, combining science(S), technology(T), engineering(E) and mathematics(M), is built upon through the inclusion of art(A) in STEAM as an opportunity to combine the mindset of the scientist with that of the artist. This is what defines one of the new and major trends in education. It can be applied both in regular classes (formal education) and also in extracurricular forms of learning (non-formal education).

In the activity "Natural Color and Color Perception", implemented in both the interest group "The World of Chemistry and Physics - Easy and Interesting" and in the physics classes, described in this report, the link between formal and informal education is clearly demonstrated in order to achieve more sustainable results through STEAM-based learning. Non-formal education develops student's skills by providing them with the opportunity to develop their creativity, which in this case is achieved through the

integrated approach between different sciences, in this case physics, chemistry, biology, mathematics, fine arts, history, Bulgarian language and literature, technology and others. The integrative relationship between these disciplines is fundamental and is part of the mixed and multi-layered model of constructivism.

Integration activities should be problem-oriented in nature, which is subordinate to the content of the subject. They make the transition from theory to practice and provoke productive thinking. This also requires a change in the standard understanding of education, namely that modern education should enable human to build his own potential and abilities. In the implementation of the activities included in the lesson of particular importance are the acquired knowledge and skills formed in the course of science education in compulsory education. The effective implementation of the formal education leads to success and proves its advantages, for example, it enables the most valuable achievements of mankind in all areas to become part of the individual and common culture of the modern human.

2 MATERIALS AND METHODS

2.1. Materials

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

- didactic: the game "Ostomachion" made by the students, a physics textbook, worksheets with tasks, questionnaires - they support the perception of new knowledge, the development of skills, as well the solution of different types of tasks requiring the transfer of knowledge towards the development of skills. Survey student's performance in the activity as well as their mood regarding what is happening as a springboard for future, person-centered science projects.

- electronic and technical resources: LiveWorksheets [1], Physics Education Technology (PhET) - online interactive simulations [2], tablets - when carrying out activities related to individual lesson components - in the actual activities when mixing colors to produce a new color and drawing geometric shapes; color mixer, laptop, touchscreen and etc.

- modelling aids: black sheet of cardboard, scissors, transparencies, colored markers, flipchart paper, glue, tape, lights, voltage source, etc. which are related to the creation of a working model of a traffic light.

2.2. Methods

The methods used in the course of the described activity are many and varied and are practically oriented. They should develop student's creative abilities as well as their critical thinking. The aim is for the learners to make cross-curricular connections and to grasp the essence of the implemented activities. Interactive methods, teamwork, discussion, modelling, etc. are used in the conducted activity, aiming at engaging the learners in team learning related to experiential learning. One of the methods particularly applicable in the session is "learning by doing" [3], allowing the implementation of activities in which the students are the active party, and that they are also the ones who, through their participation, develop their creative abilities. This method is particularly effective because, in the process, the students learn. These pedagogical phenomena in reality are themselves intertwined with many other related ones, which requires taking into account certain priorities and trends, but at the same time preserving a certain systematicity.

Another method on the basis of which the activities included in the lesson are planned is experiential learning, which is real learning through experience. Method which is achieved by putting into practice the knowledge and conclusions drawn as a result of the natural literacy formed in regular science classes. This method helps to shape responsible behavior and stimulates thinking towards idea generation. Its application is related to: the exploratory approach, the search method, the modelling, through which students work with the Archimedes game, discover the figure they should arrange with the elements of this puzzle, look for a way to construct a working traffic light with the available materials.

The team approach used prepares them for the demands of the time in which they are developing discussion skills, finding a solution and puts them in a situation to generate ideas to apply what they have learned, which helps them to form skills and attitudes to work on the topic of the lesson. These methods are complemented by others such as: brainstorming, discussion, lecture, etc.

2.3. Course of the lesson

The described lesson "Natural color and color perception" was carried out during the interest group lessons and after its testing in the regular physics and astronomy lessons within one lesson. In order to make its implementation possible and to make trans disciplinarity a reality, it is important, already when designing the thematic allocations for chemistry and physics and in order to conduct STEAM-based learning, to have comparability of the topics. Topics which are related or between which a connection can be made, as only in this way will a unified learning be provided to the students, giving them a common characterization of individual processes and phenomena. For example, in one school week, a laboratory exercise in chemistry is carried out in the course of which the students carry out experiments by which they investigate the properties of acids and bases through a number of color reactions. In the same week in Physics, the topics “Spectrum of Light” and “World of Color” are covered.

The class started with the words of Jules Verne "Anything that one can imagine, another can do", which perfectly correspond with STEAM - based learning. It is unlikely that at the time he wrote his works the author imagined that some of the devices he described would become reality: a submarine, a rocket, etc. The class continued with the color reactions in the implemented lab work by the chemistry students, as well as the topic "Spectrum of Light" covered in physics, thus introducing the theme of the class "Natural Color and Color Perception". This was followed by a connection between the color in nature and that of the Bulgarian language and literature, where the authors managed to present the spiritual color of the Bulgarian in the works currently studied by the seventh graders, which was done through talk. The relationship between the natural color and the works of art was brought out and the main colors in fine art and those of the spectrum of light were subsequently brought out. All this was complemented with an elucidation of color vision in humans by commenting on the cones located on the surface of the retina and their sensitivity to certain colors. Appropriate animation is used for this purpose. The cross-curricular link with the subject biology is particularly important, as this helps to develop natural science literacy, showing the relationship between the sciences and the unity between them.

Using a color mixing apparatus, students in the group, as assistants to the teacher, demonstrated the mixing of the primary colors, explaining each part of the experiment they showed. This unity continues by working with the graphic editor Paint, where students have the task of obtaining a new color by mixing the primary colors and drawing a geometric figure with it. Through the elements they created, a connection was made with architectural monuments left over from different civilizations and the rich colorfulness of these objects as proof that colors in nature have also excited people who lived before us. The link with history is particularly impressive for the adolescents, as it proves that people were excited about certain processes and phenomena in ancient times. The students found particularly interesting the Palace of Knossos on Crete, associated with King Minos, and the legend of the labyrinth created by Daedalus in which the Minotaur lived. It is in the capital of this island that the Museum of Ancient Greek Technology is located, where one of the exhibits is the game created by Archimedes in the 3rd century BC, known as "Ostomachion". The ancient Greek philosopher defines it as a *“spiritual game, predecessor of the puzzle. The game consists of a square base divided into 14 geometric pieces.”*[4] The goal is to shuffle these pieces in as many ways as possible using all parts of the square. Archimedes proves that each of the pieces has an area that is a rational fraction of the total area of the original square and searches for the number of possible configurations. Highly impressive to students is the fact that using a special program in 2003, it was shown *“that there are 536 unique configurations, or 17.152, if all symmetrical (by rotation, mirroring or identical triangle’s swapping) are included.”*[4] Through a game element related to following certain clues, each group finds its piece to arrange with the elements of Archimede’s game. The time to work was 5 minutes. The emotionality of the student’s work was further ensured by appropriate sound, creating a creative atmosphere and a desire to work. After a quick arrangement of the puzzles and a proper connection, we moved on to the so-called Japanese multiplication, a method for quickly multiplying large numbers without the use of calculators. Here

again the connection with the colors was made, as the line of number zero should have a red color to make it stand out from the lines of the other numbers. After explaining Japanese multiplication through appropriate examples, the students were given two problems to solve. Developing children's mathematical thinking is particularly important as this science has contact points with all others as a means of processing data and results. As the pupils worked with red and green pens in solving the set problems, the following question was given to them "Which additional color is formed by mixing these two main colors of the spectrum of light?". The answer was quickly pointed out and demonstrated by the student assistants using the color mixing apparatus. The vertical arrangement of the colors from the experiment provoked the question "Where in our surroundings do the three colors occur simultaneously and in the order in which they were observed in the experiment: red, yellow and green?". Different guesses followed, but one of those that prevailed over the others was a traffic light. At their workplaces, to the students have been given black sheet of cardboard, scissors, transparencies, colored markers, glue, tape, lights, and a voltage source. Their task was to construct a working traffic light with the materials in front of them. This was another moment where STEAM based learning provided an emotional experience for the students and an atmosphere of creativity was created. Once their work was complete, it was the moment when everyone was looking forward to switching the traffic lights on. Each team explained how they had constructed their model. It was interesting how the colors of the traffic lights were provided. Here particular attention was paid to the fact that the foils they colored acted as a color filter. After that to the students have been given task to do their homework connected with investigation the principle of color filters, and other uses of color filters, which they could demonstrate in their physics lessons when looking at the topic “The World of Colors”. This once again proves that formal and informal education are interrelated. Working moments of the lesson are presented in Figure 1.

Fig. 1. Working moments from the lesson "Natural color and color perception"

3. RESULTS

The students completed a survey exploring their performance in the activity as well as their mood regarding what was happening as a springboard for future, person-centered nature projects. The results of the whole group of students (nineteen) who participated in the activities are presented. Figure 2 presents the results of the processed responses to item 1 of the questionnaire, i.e. "To what extent do you think that the activities carried out:…". The data shows that the predominant response was “high”. A response of “cannot judge” was indicated by one student and was in relation to: “enhance your activity

in class" and "teach you independence, self-control, responsibility". The results of the processing of the answers to point 1 show that the implemented activities have very much achieved their purpose.

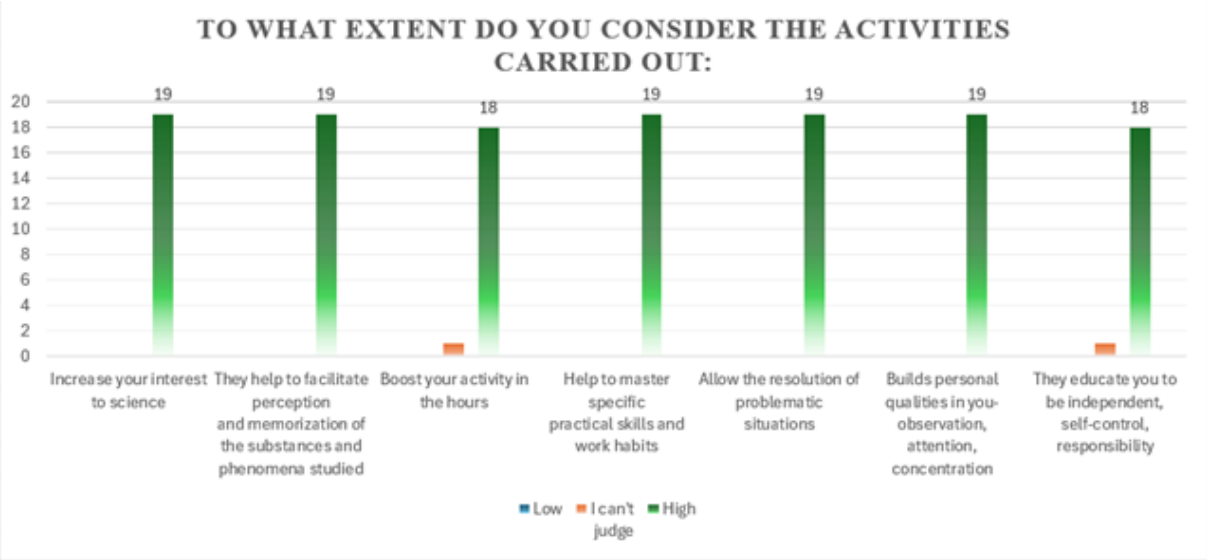

Fig. 2. Results of the processed responses to item 1 of the survey: "To what extent do you think that the activities carried out:…"

Figure 3 presents the results of the processed responses to item 2 of the survey, "Rate your level of satisfaction with the learning provided during the lesson?". The data shows that all students rated their level of satisfaction with the learning as excellent. This shows that even the answer given in item 1 "I cannot judge" does not change the student's attitude towards their degree of satisfaction with the learning.

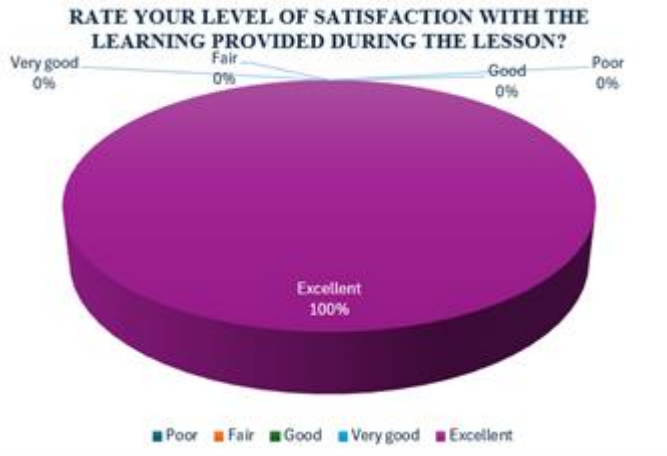

Fig. 3. Results of the processed responses to item 2 of the questionnaire "Rate your level of satisfaction with the learning provided in the course of the lesson?"

Due to the variety of activities included in the lesson it was of interest to us which activities were particularly interesting to the students. Therefore, item 3 included the following question, "Which of the activities were particularly interesting to you?". The results are presented in Figure 4. The number of

responses is higher than the number of students who participated in the activity, as some of them gave more than one.

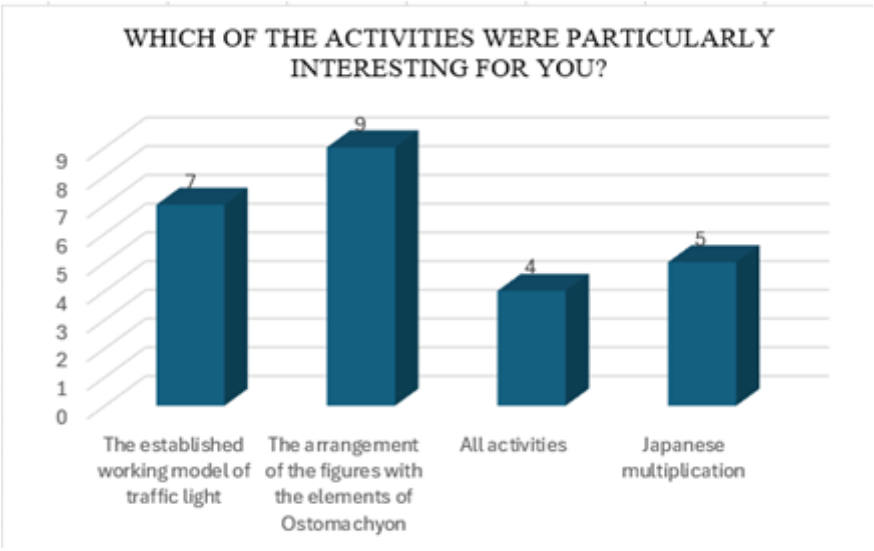

Fig. 4. Results of the processed responses to item 3 of the questionnaire "Which of the activities were particularly interesting for you?".

Any STEAM-based learning helps to overcome student's traditional perception that there is no connection between the different disciplines. Through the lesson, it was proved that there is a connection even between such sciences where it is difficult to find one.

The results directly correspond to the objectives of the lesson:

- Integrating the learning content of physics, chemistry and other sciences in the educational process by applying an interdisciplinary and transdisciplinary approach;

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

- formed skills to seek links with other sciences;

- developing competences and engineering skills in the creation of models and specimens;

- creating a model of a traffic light;

- problem solving using the Japanese multiplication method;

- constructing a model with puzzle elements;

- developing skills in applying knowledge in new contexts, analysing and synthesising information;

- developing creativity.

The lesson was held on by National Programme "Innovation in Action" was attended by teachers from Burgas, village. Ruzhitsa and Parvomai. The activities included in the lesson and the many connections made the lesson multilayered - Bulgarian language and literature, chemistry, physics, biology, history, mathematics, information technology, arts, technology and etc.

4. DISCUSSION

Discussion methods used in the course of the session were: conversation, discussion, brainstorming, debate, etc. Right from the beginning, when the topic was introduced, interest was aroused which generated questions from the students.

In the course of the lesson, many and varied interactive methods were used in the implementation of the various activities. It ends with a discussion of the task of creating a model of a working traffic light. The result is a research activity, based on the method of inquiry, to discover the principle of operation of the colored filters and to indicate other applications of them. All the activities carried out during the activity were discussed with the science teachers who attended the lesson.

5. CONCLUSIONS

Through participation in such activities, student's skills are built to carry out experiments leading to the development of student's skills in analyzing results. This activity is supportive of modern learning where students are exposed to the beauty of natural sciences and realize the usefulness of scientific knowledge. The emotional impact enhances student's intrinsic motivation and contributes to the formation of a lasting interest in natural cycle sciences, as well as helps in the formation of science literacy. Collaborative activities between students and teachers create a prerequisite for dialogue, cooperation and partnership. For the students, creative and experimental work is an opportunity to experience scientific impression and natural knowledge, for their will and motivation to be the basis and driver for quality education. For the teacher, the conducted activity is a challenge and highly valuable experience, a mechanism for forming an objective world view of the interrelationship between nature and man, between students and teachers. This can very much be related to Henry Placroze's recollections of his schooldays, described in his book "School, a Place for Children", namely *"While I was working, I felt like a scientist, though I was not. More importantly, it whetted my appetite for learning in later years."*[5]

The ideas of STEAM-based learning also have tangible points of contact with the philosophy of constructionism, which is associated not only with the creation of practical models constructed according to individual creativity and talent, but also in accordance with real possibilities. The focus is on possibilities by creating working models of devices relevant to people's everyday lives and relevant to road safety in the course of learning and teaching itself is stimulated not just for active but also for successful learning. This close conceptual link of the learning project work not only to the content but also to the final outcome is the other important starting point.

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REFERENCES

1. Liveworksheets. (n.d.). Interactive worksheets for students and teachers. Retrieved 24 Jul 2024, from https://www.liveworksheets.com/

2. PhET Interactive Simulations. (n.d.). Color vision. University of Colorado Boulder. Retrieved 24 Jul 2024, from https://phet.colorado.edu/mk/simulations/color-vision

3. Hristova, R., 2019,"Learning by doing" in non-formal education - developing creativity and applying the integral approach in physics and chemistry education, Union of Physicists in Bulgaria, Proceedings, p. 240

4. Kostanas, K., 2022, "ANCIENT GREEK TECHNOLOGY. The inventions of the ancient Greeks", Publisher: Kostanas Museum of Ancient Greek Technology", Athens, p. 167

5. Plakrouz, H., 1992, Uchilishteto – myasto za detsa, Mezhdunaroden tsentar za obuchenie i izsledvaniya, S.