PROCEEDINGS OF SCIENCE

The use of natural light for educational purposes in the formation of natural scientific literacy of students in primary school

Ruska Draganova-Hristova[a,b,*] **and Snejana Iordanova**[b]

[a] *Bacho Kiro Primary School,*
20, Filip Totyu, Veliko Tarnovo, Bulgaria
[b] *Faculty of Physics, Sofia University,*
5, J. Bourchier, Sofia, Bulgaria

E-mail: rdraganova@bkiro.info, snejana@phys.uni-sofia.bg

The study presents lessons learned in regular Science and Physics and Astronomy classes. The latter are related to an area of content – natural sunlight. An interdisciplinarity training is applied through STEAM–based learning approaches and methods: exploratory approach, experiential learning, learning by doing, small group work, etc. The opinion of the students with respect to the training was examined and presented in the study. Application of methods such as "Learning by doing", "Learning by experience" in science education is presented for: formation of natural scientific literacy, development of creativity related to making a solar device, applicable in direct teaching process. Attention is paid to the application of the above-mentioned approaches and methods as the main motivating tool responsible for building teamwork attitudes, support as well as cooperation among the students in primary school. The main purpose of the presented innovative learning approach is to make the teaching of natural sciences more fascinating for students which leads to better assimilation and durability of the new knowledge.

11th International Conference of the Balkan Physical Union (BPU11),
28 August - 1 September 2022
Belgrade, Serbia

[*]Speaker

PoS(BPU11)247

1. Introduction

The rapid development of science and technology is a prerequisite and at the same time a reason for the existence of a large number of information sources providing the necessary data on a particular problem. Of course, of particular importance in this case is the ability to bring out the main points of the information found, specifically related to the task, problem or question. This, as well as many changes in modern society, and at the same time expectations of young people, are associated with greater demands on the acquisition of knowledge and the development of skills in science.

In 2001, on the 46th Session of the International Conference on Education it was stated, "Science education should be a "triumvirate" of knowledge and understanding of scientific content, scientific methods, and science as social practice"[1]. In fact, this expression represents the essence of the concept of "science literacy". The interest on the latter is growing with the rapid development of science and technology. This is particularly related to education and the methods used in the direct work of teachers.

In the modern school, education, upbringing and training exist as a system of related goals, factors, methods and means supporting the functioning of unified, interrelated activities, the focus of which is the student. Teaching today must, to an even greater extent, guarantee children's and students' participation and expression in the educational process, cooperate in their personal growth and formation of natural-scientific literacy [2].

Science literacy is a key competence and it is important to note that one of its objectives is to develop competences through problem solving, working with schemes, didactic maps, etc. The implementation of activities through the use of project-based learning helps in the formation of natural science literacy in students of the lower secondary stage. This method is also effective in teaching primary and lower secondary students.

One of the main questions facing science teachers is how to get children interested and how to teach them to put theoretical knowledge into practice. These and many other questions are the subject of Science, Technology Engineering and Mathematics (STEM) education. It is not a curriculum now, but this kind of learning enables teachers to organize their work in a different way, which helps students to put their knowledge into practice when solving a problem. This is also related to the introduction of innovation in the teaching activity of teachers and of course it is directly oriented to students, enabling the development of their creativity.

STEM education is enhanced by incorporating the Arts into STEAM as an opportunity to combine the thinking of a scientist with that of an artist. This is what defines one of the new and major trends in education and it is an important point in introducing innovation into the learning process and helping to form science literacy. It can be applied both in regular classes and in extracurricular forms of education. The methods used in this training are many and varied, but they are all practically oriented. The choice of method should be in accordance with the objectives of the training, the selection and structuring of the learning content, and the determination of the organizational forms, methods and means by which to achieve the predetermined and formulated objectives.

The correct definition of the goal is of particular importance as it directs the search for methods and means to reach it. The selection and structuring of the learning content for a given topic or section is the main task of every teacher. This implies continuous work in the direction of improving the internal logical organization of the teaching material. The correct choice of method is of particular importance, as it is necessary on the one hand to improve existing organizational forms and training methods, and on the other, to develop new ones that are more effective and innovative. It is important that they are in line with the science lessons content.

2. Basic concept

This report presents the project and research approach, allowing the implementation of activities in which students are the active party as through their participation develop their creative potential. The method is particularly effective because in the process, students learn. These pedagogical phenomena are intertwined in reality with many other related, which requires taking into account certain priorities and trends, but at the same time preserving a certain systematic.

In the natural sciences, observation and experimentation are a philosophy of learning based on the thought processes provoked by our experience. Through it, students and teachers form and further develop their understanding of the world at different age and educational levels. This defines the main current task for the modern teacher – to offer his/her students a new generation of learning, broad-spectrum, inter- and trans-disciplinary, useful and practically applicable "in problem solving and decision making in different life situations related to science and technology"[3]. At the same time, it should be emotionally intense, rich in impressions and experiences.

Up to the sixth grade the natural sciences are studied together which is related to considering nature as unity. This requires science teachers to use methods and approaches from STEAM-based learning to implement transdisciplinarity. The meaningful project activity, the application of the research approach in the study of nature through an object is emotionally recognized by the students and provokes a serious interest among them in the natural science. For some, it could be an opportunity to discover their strengths and be their future choice.

It is transdisciplinarity that helps students to create a personal concept of the unity of knowledge. It is their motivation for acquiring knowledge, developing skills and all this is being practically oriented.

Students acquire knowledge about light already in the fifth grade in the course Man and Nature in the competence area "Electric, magnetic and luminous phenomena" [4]. Students continue to study about light in the seventh grade in the Physics and Astronomy according to competence area "Light and Sound" [5]. It was then that the students were tasked to find others application of color filters with respect to those already mentioned in the lesson "The World of Colors". This type of problem aimed to teach students to find, analyze and select relevant information for a given problem from the many available sources. During the teams' exploratory work, the relationship between sciences – Physics and Biology – was drawn. After finishing the research work, the students had trained their abilities in attractive presenting the selected information. One of the teams reported for a problem which generated a particular interest between all students. Namely, the effect of color filters on plant growth with comparison of this of natural sunlight. This provoked an intention to build an experimental set up for answering of the research question.

During organization and construction of the experimental set up, students were introduced to the methodology of scientific method. What kind of data they need to collect, how to measure them, how to structure data in an appropriate database and subsequently analyze them. Attention was paid also on the result presentation in tabular and graphical form. The latter were trained by assuring to students data from other experiments.

Before doing the experiment the students were introduced to the necessary terminology, namely what the electromagnetic spectrum is, what part of it is occupied by the visible spectrum, which was demonstrate with the help of Isaac Newton's experiment. Based on students' research and consultation with their teacher, the relationship between wavelength λ and frequency ν was also stated as $\nu = c/\lambda$, where c is the speed of light. The importance of the energy of light $E = h\nu$, where h is the Planck's constant, as a necessary condition for the process of photosynthesis was suggested. The significance of phytochromes for plant growth was touched upon.

For answering the question formulated a little above main objectives of the research work were summarized as:
• to study the effect of different colors of the light spectrum on plant's growth;
• to enrich ideas about the importance of light as a major factor in plant's growth;
• to develop skills in experimental work and stimulate responsible behavior;
• to form skills in exploring, experimenting, processing, analyzing, synthesizing and summarizing information etc.

3. Method and materials

For the investigation a decision for the use of three artificial colored lights (red, green and yellow), instead of filtering white light with color filters, was taken. They were chosen because the first two of them – red and green – are main colors while yellow is an additional color which could be formed by mixing of the others two. The choice of artificial lighting sources – conventional solar lamps – was taken with respect to decreasing the carbon footprint on nature. The sunlight was chosen as a natural source of white light. The terms mono- and polychromatic lightening sources were introduced and experimentally demonstrated via direct measurement of the emitted light from the three colored solar lamp as well as this from sun through portable Ocean Optics USB2000 spectrometer (see figure 1).

Special attention was paid on the design of the experimental set up with respect to assuring desirable colored illumination on the plants at a fixed height (see figure 2). At this stage the "technology" and "engineering" of STEAM-based education were trained.

As a plant a Daffodil was chosen because it was available during the period in which the research was provided – the month of March. The plants were planted following strict sanitary requirements in the same soil, placed in numbered pots of the same size. During the study, the plants growth was monitored, as the height of the three tallest stems in each of the plants was measured with a steel scale for a set of four days periods. The experiments were carried out under the same atmospheric environment (temperature, humidity, and gas composition) and duration of illumination of the plants. These variables were fixed with respect to the conditions at this time of the year in town Veliko Tarnovo (duration of the day, temperature and humidity). The study was done for 24 days from 01.03.2022 to 25.03.2022.

Based on their knowledge of the areas of study, the teams had formulated four hypotheses, each one related to a particular type of light. In formulating these, attention was paid to the wavelength

PoS(BPU11)247

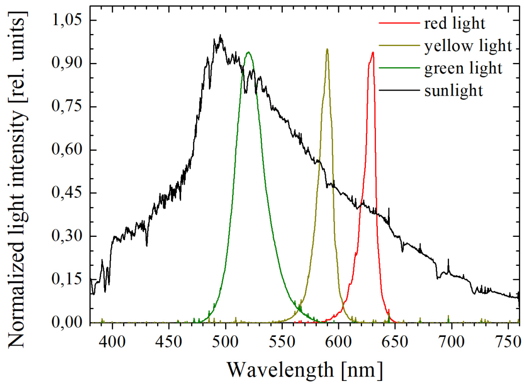


Figure 1: Dependence of normalized intensity of artificial lighting sources and of natural sunlight on wavelength in the visible range. Measurements were done with portable Ocean Optics USB2000 spectrometer.

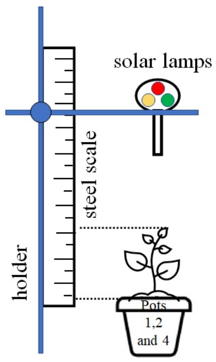


Figure 2: Scheme of the experimental set up.

and its energy, how the phytochrome in plants would react to this type of light as well as to the presence of the green dye chlorophyll.

• Hypothesis 1 was related to red light, which has the longest wavelength of all included in the study, which makes it also the lowest energy. The phytochrome found in plant cells absorbs red light, therefore the assumption made is that plant growth will be most significant under red light.

• Hypothesis 2 was related to the green light, which has the shortest wavelength, which makes it the highest energy. However, due to the presence of chlorophyll in plants, namely this wavelength are reflected, giving the plant its green coloration. In this way, the green wavelengths do not participate in the photosynthesis process, which should lead to a less pronounced stretching of plants illuminated with green light.

• Hypothesis 3 was related to yellow light having a shorter wavelength than red light and therefore greater energy than red light. At the same time, it has less energy than green light. It will favor photosynthesis, but because of the phytochromes there will not be as pronounced growth in plants as with red light.

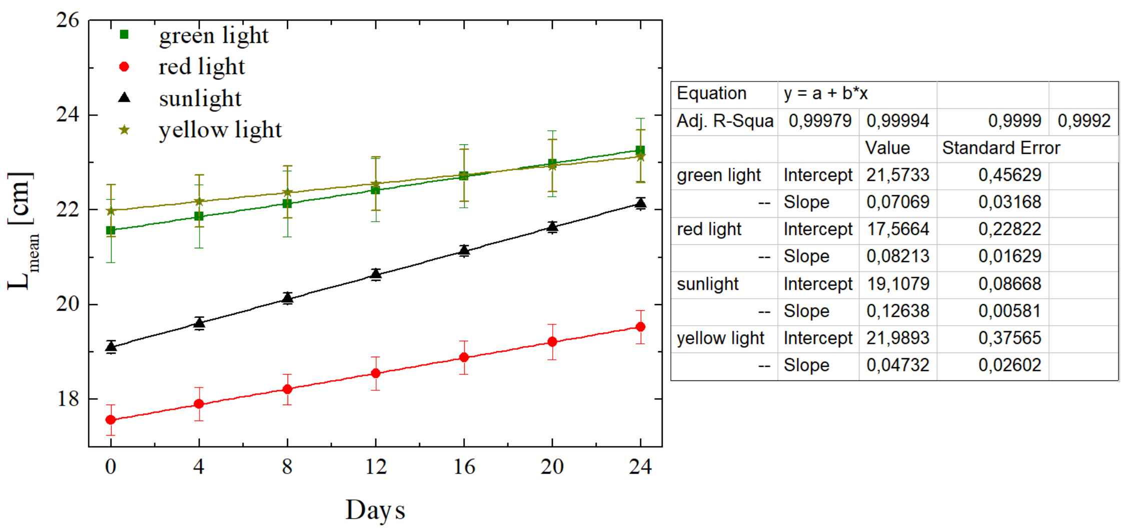
• Hypothesis 4 was related with the sunlight. It is a mixture of all wavelengths in the visible range.

The sunlight also includes shorter wavelength radiations than green, such as blue and violet, which are respectively of higher energy. Thus, sunlight turns out to have the highest energy compared to the rest of the radiations used (green, red and yellow). This suggests that under the influence of sunlight the process of photosynthesis will proceed most efficiently.

4. Results

The height of the three tallest stems in each of the plants (L) was the main parameter measured by students for a set of four days periods (see Table 1). Then a calculation of the mean value of the plant's height (L_{mean}) and its standard deviation (L^{SD}_{mean}) were done. The relative growth of plants for a period of four days was also calculated ($G_{4,mean}$=$G_{4,i}$–$G_{4,i-1}$) as well as its standard deviation ($G^{SD}_{4,mean}$). The relative growth (G_{24}) for the entire period of measurements (24 days) was also evaluated.

The next step in the education of students was the analysis of the results. They were presented in figure 3 and figure 4. As it could be seen the dependence of the height of plants on days of measurements (see figure 3) for each lightening sources was linear (linear regression was used and the data from the fits could be found in the tables on figures). The slope of the latter determines that the height of plant under sunlight changed the most significantly, followed by red, green and yellow lights. In addition, the dependence of the mean growth of plants for a set of four days periods (see see Table 1 and figure 4) revealed that it was almost constant over the entire period of 24 days.



Equation	y = a + b*x			
Adj. R-Squa	0,99979	0,99994	0,9999	0,9992
		Value	Standard Error	
green light	Intercept	21,5733	0,45629	
--	Slope	0,07069	0,03168	
red light	Intercept	17,5664	0,22822	
--	Slope	0,08213	0,01629	
sunlight	Intercept	19,1079	0,08668	
--	Slope	0,12638	0,00581	
yellow light	Intercept	21,9893	0,37565	
--	Slope	0,04732	0,02602	

Figure 3: Dependence of the height of plants, under different lights, on the day of measurement.

Based on the collected data, the students also decided to calculate the growth rate of the plants (*V*) placed under different lights. In order to determine this dependence, the students considered the relationship between path, speed and time. For path – they took the height of the plant, time – the hours during which it was exposed to light – an average of 11 hours. The formula they

Table 1: Main data values.

Light	**DD-MM**	**Days**	**L [cm]**			**L_{mean}**	**L^{SD}_{mean}**	**G_4 [cm]**			**$G_{4,mean}$**	**$G^{SD}_{4,mean}$**
	-YY		stem 1	stem 2	stem 3	**[cm]**	**[cm]**	1	2	3	**[cm]**	**[cm]**
	1.03.22	0	22,30	21,00	21,40	21,57	0,67	-	-	-	-	-
	5.03.22	4	22,60	21,30	21,70	21,87	0,67	0,30	0,30	0,30	0,30	0,00
Green	9.03.22	8	22,90	21,55	21,95	22,13	0,69	0,30	0,25	0,25	0,27	0,03
Pot 1	13.03.22	12	23,15	21,85	22,25	22,42	0,67	0,25	0,30	0,30	0,28	0,03
	17.03.22	16	23,45	22,15	22,55	22,72	0,67	0,30	0,30	0,30	0,30	0,00
	21.03.22	20	23,75	22,40	22,80	22,98	0,69	0,30	0,25	0,25	0,27	0,03
	25.03.22	24	24,00	22,70	23,10	23,27	0,67	0,25	0,30	0,30	0,28	0,03
					G_{24}	**1,70**						
	1.03.22	0	17,90	17,55	17,25	17,57	0,33	-	-	-	-	-
	5.03.22	4	18,25	17,90	17,55	17,90	0,35	0,35	0,35	0,30	0,33	0,03
Red	9.03.22	8	18,55	18,20	17,90	18,22	0,33	0,30	0,30	0,35	0,32	0,03
Pot 2	13.03.22	12	18,90	18,55	18,20	18,55	0,35	0,35	0,35	0,30	0,33	0,03
	17.03.22	16	19,25	18,85	18,55	18,88	0,35	0,35	0,30	0,35	0,33	0,03
	21.03.22	20	19,60	19,20	18,85	19,22	0,38	0,35	0,35	0,30	0,33	0,03
	25.03.22	24	19,90	19,50	19,20	19,53	0,35	0,30	0,30	0,35	0,32	0,03
					G_{24}	**1,97**						
	1.03.22	0	19,20	18,95	19,15	19,10	0,13	-	-	-	-	-
	5.03.22	4	19,70	19,45	19,65	19,60	0,13	0,50	0,50	0,50	0,50	0,00
Sunlight	9.03.22	8	20,20	20,00	20,20	20,13	0,12	0,50	0,55	0,55	0,53	0,03
Pot 3	13.03.22	12	20,70	20,50	20,70	20,63	0,12	0,50	0,50	0,50	0,50	0,00
	17.03.22	16	21,20	21,00	21,20	21,13	0,12	0,50	0,50	0,50	0,50	0,00
	21.03.22	20	21,70	21,50	21,70	21,63	0,12	0,50	0,50	0,50	0,50	0,00
	25.03.22	24	22,20	22,00	22,20	22,13	0,12	0,50	0,50	0,50	0,50	0,00
					G_{24}	**3,03**						
	1.03.22	0	21,35	22,25	22,35	21,98	0,55	-	-	-	-	-
	5.03.22	4	21,55	22,45	22,55	22,18	0,55	0,20	0,20	0,20	0,20	0,00
Yellow	9.03.22	8	21,75	22,65	22,75	22,38	0,55	0,20	0,20	0,20	0,20	0,00
Pot 4	13.03.22	12	21,90	22,85	22,90	22,55	0,56	0,15	0,20	0,15	0,17	0,03
	17.03.22	16	22,10	23,00	23,10	22,73	0,55	0,20	0,15	0,20	0,18	0,03
	21.03.22	20	22,30	23,20	23,30	22,93	0,55	0,20	0,20	0,20	0,20	0,00
	25.03.22	24	22,50	23,40	23,50	23,13	0,55	0,20	0,20	0,20	0,20	0,00
					G_{24}	**1,15**						

used is $V = \Delta G/\Delta T$, where ΔG is the difference in Daffodil plant height between two adjacent measurements in meters, and ΔT is the time difference between two measurements in seconds. Since the measurements were between 4 days, $\Delta T = 4 \times 11 \times 3600 = 158400$ s. The students' calculations are presented in Table 2 and illustrated in figure 5. As well as, the dependence of the mean growth of plants for a set of four days periods (see figure 4), the growth rate stayed almost constant over the entire period of 24 days. The data analysis was from the part of "mathematics" in STEAM-based learning.

From the analysis of the results presented in tabular and graphic form the main conclusions for rejection or acceptance of the relevant hypothesis were done. The team was particularly pleased to see that their hypotheses were confirmed.

In carrying out an evaluation of the experiment, attention was paid to how it could be improved.

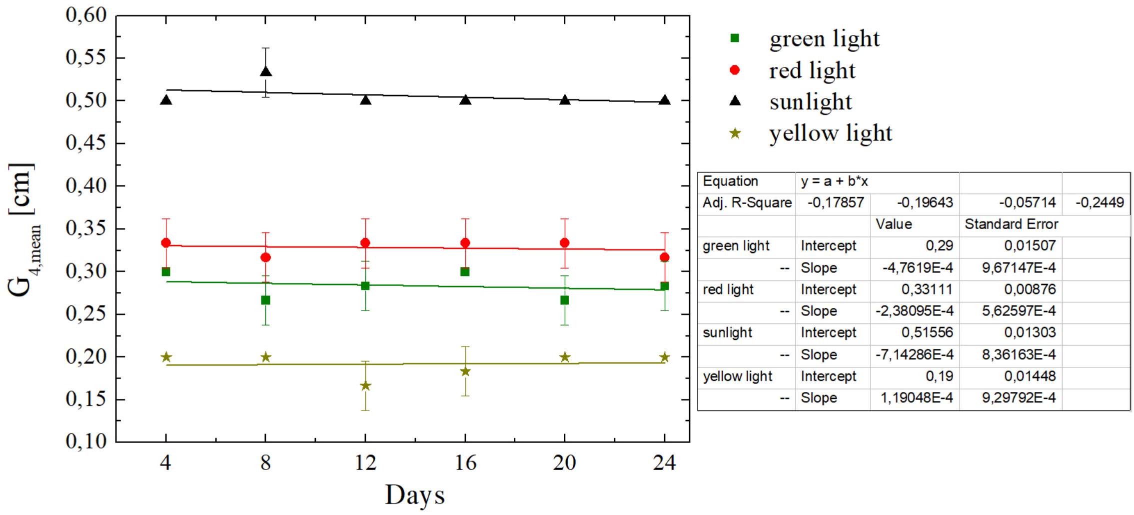


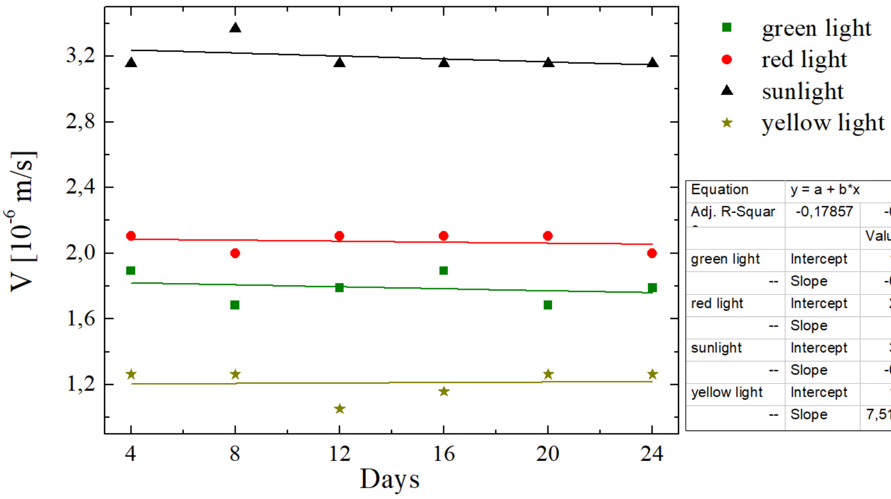
Figure 4: Dependence of the mean growth of plants (under different lights) on a set of 4 days periods.

Table 2: The mean growth rate of the plans (under different lights) on the day of measurements.

DD-MM -YY	**Days**	**L_{mean} [cm]**				V[10^{-6} **m/s]**			
		Green Pot 1	**Red Pot 2**	**Sunlight Pot 3**	**Yellow Pot 4**	**Green Pot 1**	**Red Pot 2**	**Sunlight Pot 3**	**Yellow Pot 4**
1.03.22	0	21,57	17,57	19,10	21,98	-	-	-	-
5.03.22	4	21,87	17,90	19,60	22,18	1,89	2,10	3,16	1,26
9.03.22	8	22,13	18,22	20,13	22,38	1,68	2,00	3,37	1,26
13.03.22	12	22,42	18,55	20,63	22,55	1,79	2,10	3,16	1,05
17.03.22	16	22,72	18,88	21,13	22,73	1,89	2,10	3,16	1,16
21.03.22	20	22,98	19,22	21,63	22,93	1,68	2,10	3,16	1,26
25.03.22	24	23,27	19,53	22,13	23,13	1,79	2,00	3,16	1,26
					V_{mean} [m/s]	**1,79**	**2,07**	**3,19**	**1,21**

The students indicated that the experiment could be developed in the direction of examining the amount of starch in the leaves of the Daffodil plant, which now includes the science of Chemistry and Environmental protection. They pointed out that this was of particularly importance because the more starch, the more chlorophyll, which meant that the plant has photosynthesized more. It was noted that the duration of the experiment, the tools for doing the measurements and the season in which they were provided, were also important.

As a last educational part, the students made conclusion. The team highlighted the dependence that exists between light and plant growth. The relationship between the sciences was also indicated, which was evidence that each science cannot be considered in isolation from the others, especially those in the natural science cycle. Attention was paid to the fact that the data collected were reliable



Equation	y = a + b*x			
Adj. R-Squar	-0,17857	-0,19643	-0,05714	-0,2449
		Value	Standard Error	
green light	Intercept	1,83081	0,09511	
--	Slope	-0,00301	0,00611	
red light	Intercept	2,09035	0,05533	
--	Slope	-0,0015	0,00355	
sunlight	Intercept	3,25477	0,08223	
--	Slope	-0,00451	0,00528	
yellow light	Intercept	1,19949	0,09144	
--	Slope	7,51563E-4	0,00587	

Figure 5: Dependence of the growth rate (under different lights) on a set of 4 days periods.

and fall in line with expected results.

The investigations on this project-based problem were presented to the National Competition "Young Talents" of the Ministry of Education and Culture and received an incentive award as well as funding for their future projects. The project presentation allowed development of students' creative and imaginative talent which was part from the "art" in STEAM-based learning. The ideas of project-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 [2].

5. Conclusion

The model of education is being updated, it becomes more interactive, innovative and attractive. STEAM tends to be a necessity as it activates students' attention, mental activity and forms students' natural science literacy already in primary school. STEAM-based learning increases students' motivation to learn and also enables more effective teamwork. All of this encourages independent thinking, as the main feature of STEAM is hands-on and project-based learning, developing creative problem-solving skills. In the future, education will require persistence and sustainable development of creativity and innovation, and creative thinking is our natural endeavor.

Acknowledgments

The article was prepared with the financial support of the Research Project in support of PhD students at Funding agency FNI, Grant number 80-10-22/10.05.2022.

References

[1] 46th session of the International Conference of Education (Geneva, 5-7 September 2001), Working documents, 2001.

[2] R. Hristova. "Learning by Doing in Informal Learning - Developing Creativity and Implementing the Integral Approach in Physics and Chemistry Education". *Union of Physicists in Bulgaria, Proceedings*, 2019.

[3] Centre for Quality Control and Evaluation of School Education, Ministry of Education and Science. "The Challenges of School Education". Sofia, 2013

[4] Curriculum of Sience V grade https://www.mon.bg/bg/2000.

[5] Curriculum of Physics and Astronomy VII grade https://www.mon.bg/bg/1690.