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IBSE METHOD IN ASTRONOMY TEACHING

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Abstract. The paper concerns astronomy teaching in Serbia. A special attention is paid to the teaching on the levels lower than university. The syllabus contains many topics which, no matter how strong efforts of teachers are, cannot be treated otherwise than by applying monologue. Application of a method, rather unknown in our milieu, can substantially improve the methodology in astronomy teaching. Its name is IBSE - Inquiry Based Science Education involving Experiment. A particular example of applying IBSE is described in detail.

The interest in astronomy in general, including also teenagers (pupils), can be best described by quoting Immanuel Kant (1724-1804): “Two things fill the mind with ever-increasing wonder and awe, the more often and the more intensely the mind of thought is drawn to them: the starry heavens above me and the moral law within me”. However, the interest or, the state of being fond of astronomy, appears as a mere beginning on the thorny road of learning about celestial phenomena and including this subject in the teaching process. The scientists and teachers are aware of this fact because of their choice of profession. A completely different situation is met in the case of pupils. Their initial enthusiasm is gradually weakened by experiencing that astronomy is a complicated science requiring a multidisciplinary knowledge including mathematics, physics, chemistry etc. Astronomy teachers must overcome this problem.

Astronomy is the oldest science. In favour of this are images of constellations and attempts of time reckoning in the oldest living places of human race - caves [3-5]. Studying, training and teaching astronomy has advanced, directed and monitored thinking and science during the entire civilisation development. In Serbia astronomy was taught at first at the Faculty of Philosophy in Belgrade, later the department of this faculty for mathematics and natural sciences became a separate faculty where, finally, astronomy got its own department [10]. In the secondary school (gymnasium) astronomy had been taught in the framework of geography, to become a separate subject in the second half of the XX century. As for the primary school, astronomy is still present in teaching subjects named knowing nature, the world around us and geography.

There are two kinds of problems following teaching astronomy in Serbia. The first one concerns qualified teachers. In gymnasiums astronomy is still taught by physicists (not only by physicists, but also, due to lack of physicists with bachelor degree, by completely unqualified persons - SN) who during their undergraduate studies had no subject of astronomy or astrophysics. This was the situation also when astronomy existed as a separate subject, but from the time when astronomy entered the syllabus of physics, it has been manifested more strongly. In the last gymnasium form for classes of science and mathematics it is foreseen to devote to astronomy one lesson a week, out of the total of five which belong to physics. The majority of teachers even that lesson use to teach physics additionally! In the case of classes oriented towards humanitarian sciences the material of physics for the last form contains astronomical matter, it should be treated near the very end of the school year, but usually even then the pupils get no information on astronomy! [8]

The second kind of problems has a methodological nature. The material contains many topics which, no matter how strong efforts of teachers are, cannot be treated otherwise than by applying monologue. This is mainly an organisational problem! In order to overcome it one should organise a sufficiently large number of astronomy workshops through which astronomy teachers would become skilled to solve a majority of methodological problems. The Society of Astronomers of Serbia is expected to be seriously involved in improving astronomy teaching in Serbia. It could do this by forming a competent commission. The commission task would be to propose new syllabus and curriculum for astronomy teaching. Our recommendation is that the syllabus should not be too large so that according to the curriculum a sufficient number of classes could be devoted to observations and experiments (classes of hands-on type). We also point out that gymnasiums which possess proper equipment and software concerning astronomy are rare. Beyond the large centres, like Belgrade, Novi Sad, Niš, etc, this is expressed more strongly, because of the problems with a permanent access to Internet, video devices in specialiced classrooms, not to mention ordinary classrooms! Therefore, it is not surprising that the results of the pupils, as well as teaching astronomy in general, do not satisfy strong criteria.

The present paper is not aimed at dealing with the first kind of problems, it is aimed at giving contribution to the modern methodological approach in teaching astronomy by using the IBSE method.

A PEDAGOGICAL EXPERIMENT

Using his knowledge acquired during undergraduate, MsC studies in astrophysics and PhD studies in methodics of teaching physics and consulting his colleague from the Astronomical Observatory in Belgrade the first author carried out a pedagogical experiment in September 2013.

This pedagogical experiment containing parallel pupil groups has confirmed that it is justified to include IBSE (Inquiry Based Science Education involving experiment, research, self-organised work, critical thinking, treatment of the results and drawing conclusions on the basis of the results, as well as a written report at the end, [2]). The IBSE method is basically a scientific method which has existed even from the time of Galileo, in modern methodics it is also known as integrated scientific method, [7]. The dependent variables were scores of pupils, the independent variables were learning methods.

The sample was formed by three classes (90 pupils). All the three belong to the same orientation (science and mathematics), same form (fourth, the last) and school (Šabačka gimnazija, Šabac Gymnasium). The quality of groups was approximately equal, which is confirmed through the general score in learning and the average mark in physics. The first class formed the Control Group (K). In their case Kepler’s laws were taught in the classical way, the so-called transmission method, in which the pupils listen and the teacher speaks to them (lecturing and adopting knowledge) and all what the teacher uses are blackboard and chalk [6]. In the case of the experimental group 1(E1), the second class, the experimental factor, or independent variable, is the teaching following IBSE. In the second experimental group 2(E2), the third class, the experimental factor is the teaching supported with a demonstration experiment and multimedia. At the end of the study the final knowledge evaluation was done in each group. This evaluation was carried out by means of a test.

The study was aimed at establishing if the teaching following IBSE enlarges the quantity of knowledge of the pupils. On this basis the tasks were defined and the hypotheses formulated: the zero one (IBSE has no influence upon the knowledge of the pupils, i. e. the groups have equal scores) and the alternative one (IBSE leads to enlarging in the quantity of knowledge of pupils, i. e. there are statistically significant differences among the groups). In the treatment of the results the descriptive statistics with its parameters was used. In order to establish statistically significant differences in the results the variance analysis (ANOVA) was used, as well as the tests of Tukey, group and individual [9].

APPLICATION OF THE IBSE METHOD IN TEACHING KEPLER’S LAWS

The topic *Kepler’s laws* appears as one of the best examples for application of IBSE. These laws played an important role in the history of science in the way that their validity contributed significantly to eliminating the illusion of the geocentric system which had been a problem from Aristarchus to Galileo and Kepler.

In the case of the experimental group during the lesson *Kepler’s laws* were explained theoretically. The lesson started with the problem formulation and forming the hypothesis. For the purpose of simulating the initial studies from the time when the geocentric theory was accepted and sky was naked-eye observed, the teacher suggests the pupils that the initial hypothesis is: All celestial bodies move around the Earth!? In the next step one analyses the appearance of the sky over day-light and night and looks for the answer to the question: why when observing from the Earth it seems that stars and planets move around us (geocentric theory)? One explains the reasons for which the geocentric system persisted for so long time, also the historical importance of thinkers, like Aristarchus from Samos, who was the Library Director in Alexandria (II century BC). Aristarchus was the founder of the heliocentric system. Its doctrine for many reasons was neglected and the heliocentrism is attributed to Copernicus (1473-1543). The time difference of 18 centuries shows clearly that the road of acquiring scientific knowledge was hard, but nevertheless as such, the only right way. The teaching is continued through experiment Martian orbit [1] which has been conceived on the basis of Kepler's original work. For the necessities of the experiment the pupils were divided into groups. The special classroom for physics has been prepared for working of seven groups of pupils simultaneously. Every table contaned the group designation and every pupil at the moment of entering the room was given an identification card with the group designation (Fig. 1.).

Figure 1: Exercise Martian orbit.

During the process the pupils participate in the IBSE phases: *Problem Definition,* Motion of Celestial Bodies; *Collecting the Data:* coordinates of planet Mars; *Formulating Hypothesis:* All celestial bodies move around the Earth!?; *Experiment:* The pupils are trying to draw the orbit of planet Mars with the Earth at the origin, (geocentric system) - a failure! Now the pupils are drawing the orbit of Mars again, but this time with the Sun at the origin (heliocentric system) – a success!; *Testing Hypothesis:* Bearing in mind the result of the experiment the pupils conclude that the initial hypothesis is wrong; *Conclusion:* Mars, just as the other planets, moves around the Sun!

In doing the experiment the pupils use the material necessary to the implementation and applying their general knowledge, they analyse its course and infer the shape of the orbit: as the first approximation one assumes a circular orbit centred on the point *G* shifted with respect to the circle centre (Fig. 2); the positions of the two planets, Earth and Mars, are determined on the basis of the circle centre which is also the centre of the ellipse; the centre of the circle (ellipse) and the centre of the auxiliary circle are along the same straight line, *AP*, which connects the perihelion and aphelion of the orbit.

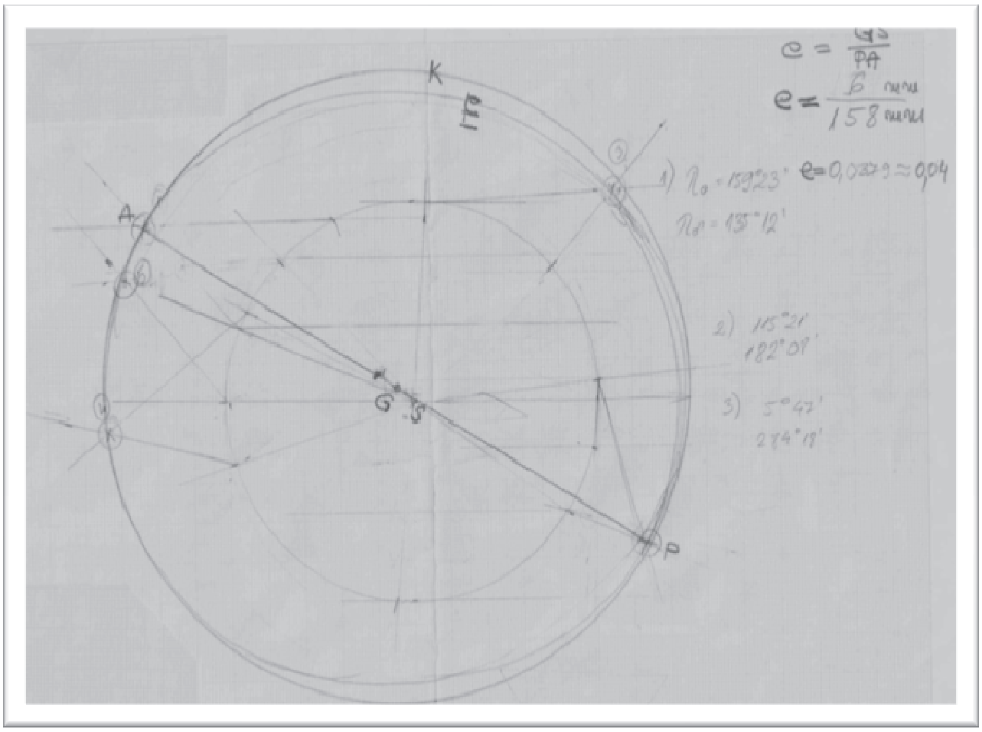

Figure 2: Drawing the orbit of Mars, a pupil's work.

The centre of the auxiliary circle is one of the foci of the ellipse at which the Sun is situated; the position of the other focus is found by measuring the length of the segment *GS* (Fig. 2) and then the obtained value is used in the opposite sense with the origin at *G*. Using a pair of pins and a thread the pupils should draw the ellipse; finally they infer the eccentricity of the orbit. In most cases the pupils completed their task at school, the other ones might complete it at home, to bring then the drawing and show it to the teacher.

RESULTS AND DISCUSSION

The descriptive statistics of the final test shows that the quantity of knowledge was highest in the case of E, and lowest for Group K. The values of the descriptive statistical parameters indicating this fact are given in Table 1:

TABLE 1. Descriptive statistical parameters for the final testing

Group	AS	SD	Se	CV	Min	Max
Control	18.25	3.25	0.7623	18.46	11.00	25.00
Experimental 1.	24.35	2.72	0.6873	10.43	19.00	30.00
Experimental 2.	21.95	2.92	0.6886	13.30	18.00	29.00

AS – arithmetic mean, SD – standard deviation, Se – standard error of arithmetic mean, CV – variation coefficient and (Min, Max) – variation interval

The analysis of the descriptive statistical parameters for the final test shows that the highest value (number of points) occured for E1, it was 24.35 with a standard deviation of 2.78. The lowest value occurs for Group K:18.00±7.00. The variation coefficient for K is 18.46% being the highest value for this parameter. It is due to the large variation interval (14 points). In E1 and E2 the variation coefficients have values of 10.43% and 13.30%, respectively. With respect to all parameters examined here these are the smallest values, the data were homogeneous, and the variation intervals for both groups were equal to 11 points.

The results of the final test allow to establish a high quantity of knowledge in E1 and E2, compared to Group K. Between E1 (82.50%) and E2 (73.83%) there is a difference in the knowledge quantity. The circumstance that it is higher in E1 than in E2 can be explained by introducing IBSE.

The plot of knowledge quantity is presented in Fig. 3:

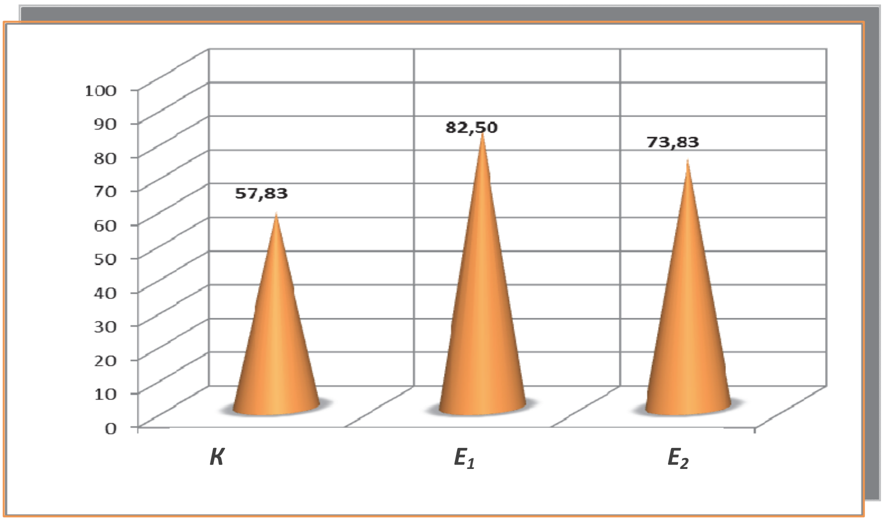

Figure 3: Knowledge quantity for pupils in % for the final test.

The statistical significance for the differences between the examined groups for the final test is given in Table 2.

TABLE 2. Statistical significance of differences

Group	AS	Experimental 1.	Experimental 2.	Control
Experimental 1.	18.35	/	1.60	**6.35***
Experimental 2.	24.35	/	/	**5.20***
Control	21.95	/	/	/

** r<0.01 – significance coefficient*

The significance of the differences between the groups is determined by using a completely random plan. The value found here *F* (23.22) indicates existence of very significant differences (p≤0.01) between the groups examined here. The difference significance between the experimental groups individually is established by using Tukey's test. In this way one finds a very significant difference (p≤0.01) between K and E1 (6.35), as well as between K and E2 (5.20). The hypothesis that the groups E1, E2 and K are equal is not acceptable, which means that the work following the Enquiry Method has an influence on the process of learning the syllabus elements and quantity of knowledge. Between other groups participating in the experiment no significant differences are found (p≥0.05).

Based on the analysis of the present results it is possible to conclude that the alternative hypothesis: the IBSE method enlarges the quantity of knowledge for pupils – there are statistically significant differences between the groups, is here confirmed. In other words applying the IBSE method results in a higher quantity of knowledge for pupils; therefore this method appears as an efficient one and it deserves to be recommended to the teachers!

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