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An IBSE (Inquiry Based Science Education) approach in teaching sciences using external environment of the school and computing platform

ABSTRACT

During the 2010 - 2012, Serbian schools participated in the "Greenwave" project funded by the European Commission under the 7th Framework Programme for research and technological development. Looking at the arrival of spring, "Greenwave" promoted an inquiry-based approach through different European school systems. More than 2000 Serbian Primary School and the Low Secondary School students, and about 100 teachers of different skills participated in field observations and followed arrival and progress of the spring. Students were trained in construction and implementation of improvised models of rain gauges and anemometers, and taught how to write down the air temperature. They also followed appearance of four species, very early signs of spring: the swallow (*Hirundo rustica*), the common European frog (*Rana temporaria*), horse chestnut (*Aesculus hippocastanum*), and ash tree (*Fraxinus excelsior*). Data about species was submitted in two ways: as an Official Record or as Observation. Pupils also tried themselves in using digital camera and cell phone and in processing images. All data and sightings were uploaded on interactive parts of the official web site. „Greenwave" inspired teachers to practicing inquiry method, trying the innovative approaches and implementing a multi-disciplinary way of teaching. Working on this project, Serbian scholars applied process of measuring, monitoring and observation and intensively used the external environment of the school. Also, such kind of work provided the possibility of inclusion of students of different ages, abilities and skills, and of different levels of knowledge, as well.

Key words: signs of spring, interactive learning, IBSE

Introduction

Within the present school system in Serbia and many other European countries, teachers mainly teach science via lectures, children rarely resolve experimental problems or projects by themselves, and parents are interested in children's grades rather than in their skills and competencies. In order to overcome this situation, we made initial steps to implement an inquiry-based approach in teaching sciences as a new and innovative way of gaining knowledge in primary schools. Inquiry-based approach (IBSE) is based on developing different situations in which pupils are asked to observe and make question about certain natural phenomena. They are encouraged to support or contradict their opinions and theories, and draw their own conclusions from experimental data (independent practice). Such learning situations are meant to be open-ended and they do not aim to achieve a single "right" answer for a particular question being addressed (Hattie, 2009). Practicing inquiry method allows opportunity to explore new ways in creating effective links between different school curriculum, supports multi-disciplinary way of learning and better using external environment of the school (Harlen, 2010). The inquiry-based approach is approved to produce transferable critical thinking

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skills, improved achievements, and improved attitude towards the subject. Shymansky et al. (1990) found greater effects of inquiry based teaching on process rather than on content. However, the effects are greatest at elementary level and decreased as students progressed through the educational system. Hattie (2009) underlined that it could have “powerful effects where students have the cognitive capacity to think critically but have not previously been encouraged to think in this way”. Similarly, Bangert-Drowns and Bankert (1990) found clear evidence that inquiry based method can foster critical thinking amongst students.

In 2001, the IBSE method was introduced in primary school science education in Serbia for the first time. In collaboration with French Academy of Sciences, a *Hands-on* (fr. *La main à la pâte*) approach was implemented in order to uplift and revitalize teaching of the sciences. In 2003, Serbian Ministry of Education approved an optional course *“Hands on – Discovering the World”* for Primary School curriculum. The basic idea for introduction of this course based on IBSE was to foster, encourage and develop children's critical thinking and curiosity. Course lasts about thirty hours annually and gives children opportunity to meet science through experimentation (Jokić, 2007; Bošnjak & Obadović, 2009; Bošnjak et al., 2010; Miličić et al., 2010). To date, more than 20 books have been translated into Serbian, originally created by the French *La main à la pâte* team (http://www.fondation-lamap.org/). There is also the Serbian web-site http://rukautestu.vinca.rs, the semi-mirror of the French www.inrp.fr/lamap. It contains more than 2500 pages in Serbian with scientific and educational content for different class activities.

Since 2010, Serbian schools have participated in the “Fibonacci” project (www.fibonacci-project.eu) funded by the European Commission under the 7th Framework Programme for research and technological development. “Fibonacci” was designed to test possibility of implementation inquiry-based learning methods in science and mathematics through different European school systems (Starting Package, 2010). The basic ideas of Fibonacci were: working in a scientific manner, securing basic knowledge, cumulative learning, developing a problem-based learning and learning from mistakes. Also, some of the goals of “Fibonacci” were: interdisciplinary approach, promoting equal participation of girls and boys, promoting autonomous learning and students' cooperation. The main purpose of these approaches was to create changes in teaching and learning sciences in schools across Europe.

In the frame of “Fibonacci”, participants also participated in the “Greenwave” Project. This was a collaborative science project designed to observe the onset of spring in Europe based on the IBSE. During the one-year preparing period (2010) and two consecutive experimental seasons (2011 and 2012), Serbian schools participated along with 16 other countries of Europe. The Project was designed to develop and promote on-line collaboration and dissemination, and rapidly become widely known and approved among teachers, pupils and their parents. In this paper, we report about Serbian activities on practical implementation of IBSE through “Greenwave”, and discuss our own experiences, observations and contributions to the Project.

Materials and Methods

Preparing activities

In the preparing year of the Project (2010), we were mainly focused on establishing the network of Serbian schools interested in participating in “Greenwave”. During this period, teachers practiced mainly the classroom activities in order to prepare students to practical work, according instructions found on the official web site (www.greenwave-europe.eu). Students were trained in construction of models of rain gauges and anemometers, some of the most important instruments found in any weather station (Figure 1). Also, they were taught how to read the thermometer and write down the measured temperature.

Figure 1. *Construction and testing of 'anemo'.*

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Students also learned about four species, very early signs of spring, which were monitored through the Project: the spawn of common European frog (*Rana temporaria*), the swallow (*Hirundo rustica*), horse chestnut (*Aesculus hippocastanum*), and ash (*Fraxinus excelsior*). Frogspawn and swallow were selected as the mandatory species common for all European countries. Here are some basic information and instructions about the species to which attention should be paid during the field work: 1) When frogs wake up from hibernation, and how to find the frogspawn in a pond or ditch? 2) Each spring swallows return from Africa to breed. Swallows build their nests inside sheds and barns, so they have to find them; 3) To find a horse chestnut, students should remind themselves where they collected conkers last autumn, and 4) Ash trees are very common in hedges, parks and gardens; because young ash trees get their leaves before mature grown trees, it is recommended to look only at ash trees that are at least five meters high, to be sure that they are mature.

Students are also given the guidance on how to make wall chart/posters with their predictions, opinions and theories, for comparison during, and at the end of the project. In this way, they were able to compare their initial predictions with those from the other participants.

Participating in field observations

During the 2011 and 2012, between February and June, students practically participated in field observations, and followed signs of the arrival and progress of the spring (Figure 2). They also practiced themselves in using of their hand-made measuring instruments. The weather measurements were taken every day in the same place and at the same time. For measuring wind speed, students expounded their instruments outside and, count the number of times the coloured cup spins around in one minute. Students also measured the rain amount collected in the rain gauge container over 24 hours. Later, they calculated a total rainfall at the end of each week and converted rainfall data from millilitres to millimetres, using formula:

$$l/m^2 = (0.001\ m^3) / (1\ m^2) = 0.001\ m = 1\ mm$$

Also, students wrote down the temperature measurements on daily basis, and calculated average temperature for each week/month during the period of monitoring.

Participants submitted the species sightings in two ways: as an Official Record or as Observation. Official Record is when students observed a species in the state associated with the arrival of spring (tree is in bud-burst, or frogspawn occurred in the pool for the first time). The Observation means that some species could be noted before they reach the required state for an Official Record, or after then (e.g. when frogspawn has already developed into tadpoles or adult stage, or when bud-burst have developed into the bunch of green leaves…). To record Official and Observation data, pupils should use a digital camera and cell phones. Then, they processed images using Picture Manager and similar legal software. All required data (the weather measurements, sightings images and comments) schools uploaded to the interactive parts of the official web site www.greenwave-europe.eu.

Figure 2. *Collecting and noting climatologically data.*

Using a computing platform

A public sharing of collected data was provided through the network service (using the JavaScript internet platform) designed to make the information on the website accessible to all participants. After logging on the site, students and teachers were able to further customize and develop content of the platform (accessed via 'My Greenwave' page). Uploaded data were used to generate maps and charts, showing the arrival of the spring across Europe. The Photo Gallery with original photos provided a visual record of the early signs of spring. During the last year of the project, teachers were also allowed to upload or stream live videos, and participate in experts discussions in forums.

Results

At the first year of participation, 39 Serbian schools participated, with 58 teachers and 1435 pupils. In the next two years, the number of teachers increased to 102. In 2012, the number of schools interested in “Greenwave” was raised to 45, and even 2181 Serbian primary school students were involved in “Greenwave” experiment. Teachers of different skills (biologists, physicists, IT specialists, chemists, teachers

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in primary schools, and the pre-school teachers…) were included in all project activities. The ratio between schools from rural and urban areas was nearly 2:1 in favor of urban schools, partly because of good computer facilities and better internet connections in urbanised parts of the country (Figure 3).

Greater interest in measurements and observations was noted among children aged 7–10 years (Figure 4).

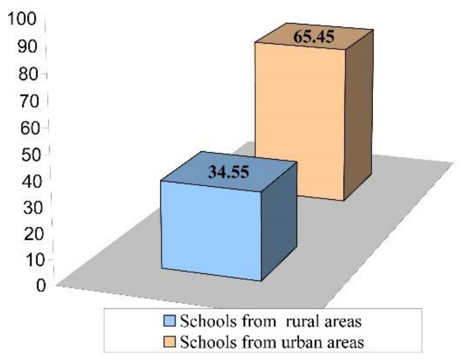

Figure 3. *The urban/rural schools profile.*

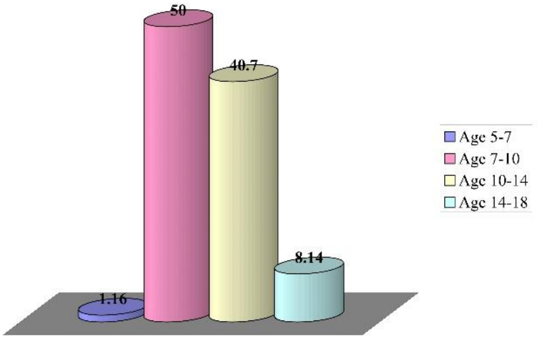

Figure 4. *The age ratio of participants.*

In 2011 and 2012, from late January to the end of June, students measured the weather conditions and uploaded data, sightings and observations on interactive parts of the web site (Figure 5). At the same time, they made own personal notes and classroom wall-posters (Class Wall Charts) with summarized results of their measurements. As it was mentioned above, students monitored indicators of the arrival of spring: the common European frogspawns and the barn swallow, and also two local trees: ash and the horse chestnut. A total number of Official Records and Observations submitted from Serbia in 2011 were 724 (72 Official Records and 652 Observations), as well as 488 (49 Official Records and 439 Observations) in 2012. These data were used to generate maps and charts on the site, showing the arrival of the signs of spring in Europe. The Photo Gallery on the web site also provided a visual record of the work being done (Figure 6).

Figure 5. *Personalized interactive space for the input of weather data (www.greenwave-europe.eu).*

Figure 6. *Original photos taken by Serbian students (selected from the Photo Gallery), in the order: the Horse chestnut, European frog, the Ash, the Swallow. Upper row: Observations. Bottom row: Official Records.*

Majority of species were noted between 14 – 17 weeks of monitoring. The number of observations peaked in week 14, from April 4^{th} to 10^{th} (Figure 7). The most commonly reported were the records of Frogspawn and Horse chestnut. At the end of the experiment, using the interactive Sightings Timeline Map (www.greenwave-europe.eu), students could conclude that spring spreads from south-western towards the eastern parts of the continent.

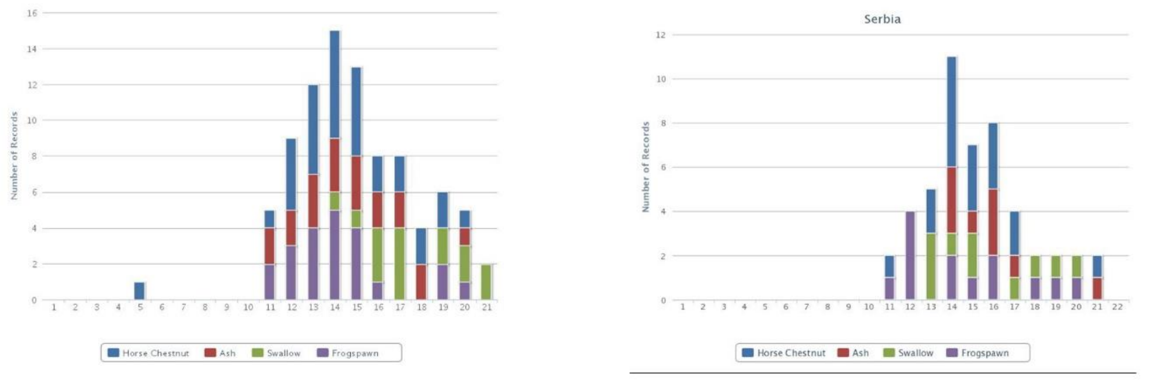

Figure 7. *Official Records from Serbia recorded each week during the spring 2011 (left) and 2012 (right). The horizontal axis represents the week number, with week 1 commencing on the first of January. Records for each of the weeks are divided in different colours to display species and number of records which were submitted.*

In order to rise social awareness and promote the IBSE and "Greenwave", teachers, students and other team members had many interviews for Serbian National Broadcasting Corporation and regional and local media. Also, several reports about their activities were published in the Serbian Educational Weekly Journal and distributed around the country free of charge.

Discussion

Working on "Greenwave" project, Serbian scholars applied process of measuring, monitoring and observation, and intensively used the external environment of the school. „Greenwave" inspired teachers to try innovative approaches, and enabled students to develop capacity for analysis and synthesis, enhancing their ability to notice important details. Applying this kind of work, pupils aquire the active role in class activities, better meet the world around them, and play by researching and experimentation.

During three-year duration of the project, pupils adopted some of the basic rules of measuring and presenting main physical parameters. One of the most important rules is that when scientific measurements are taken, the significance lies not in the single measurement, but in its place as part of a set, or series of measurements. Further, all measurements should be taken in same way (i. e. in the same place and at the same time of the day), so that they can be compared fairly. Also, it is important that the measurement place should be in the shade (for temperature measurements) and at location where the wind can blow freely (for the wind measurements). It is important, too, to make sure if the rain gauge is positioned where it cannot be knocked accidentally by dogs, cats or children. Beside these basic rules, students could upgrade their knowledge about the ways of common presenting of physical parameters. For example, most of students have already heard from the weather forecast on TV that the wind blowing is presented in kilometres *per* hour. During the classroom discussions, students could find out that the weather forecasters' anemometers convert the revolutions *per* minute into kilometres *per* hour, and that their model of 'anemo', however, could only give them an approximation of how fast the wind is blowing.

An IBSE approach provides possibility of inclusion of students of different ages, abilities and skills, and of different levels of knowledge. For example, students who are more skilled in technical operations mainly participated in construction of measuring instruments. Average skilled students were involved in reading and noting data, while students better in math and physics are able to calculate average values of the temperature or of total precipitation during the certain period. With the help of their teachers, they converted their rainfall data from millilitres to millimetres, using an appropriate formula. Further, pupils better in artworks and visual presentation were engaged in making classroom-wall posters, while those more skilled in computer science updated data on the website.

In Europe, spring officially occurs between mid March and mid June, however, as could be seen from the species observed during the "Greenwave" experiment, the first clear indications that spring has sprung can be seen well before, in the first part of March (which could be related with the global climate change). Of the various species, the horse chestnut and the frogspawn were observed first, both in Serbia and in the most other European countries.

Following the project activities, students also had the opportunity to learn more about species – very early signs of spring, and deepen their knowledge of nature and biology. For example, they usually know that swallows flies off to warmer climates in Africa, but in spring return here to breed. During the field work and class discussions, they could also learn what causes this migration: swallows feed on insects, which they catch in their beak as it flies through the air; but, there is no enough food during the winter in Europe, and they have to fly towards areas with warmer climate to survive an unfavorable season. Then, swallows return in spring to breed. They take advantage of the longer days in Europe, and have enough time to collect flying insects to feed their young. By following occurrence of frogspawn, pupils could learn that when spring comes, frogs wake up from the winter hibernation, and large number of individuals both males and females, come to the breeding ponds and ditches, where they were born themselves to produce frogspawn. The females lay eggs encased in jelly, which are fertilised in the water by the males. The fertilised frogspawn floats on the surface of the water; it is a clear jelly with embryos that are visible as black spots.

Similarly, following signs of spring students could enhance their knowledge in the field of botany. Students' first attention was drawn to the very characteristic twigs and buds of the horse chestnut tree. The twigs have marks that look like tiny horseshoe prints (left by last year´s falling leaves) and the end bud on each twig is brown and very sticky. When the bud opens, it can be seen green colour of the new leaves inside, which marks an early start of the new season. The horse chestnut is very common and widespread tree in parks and along the streets. It is supposed that students were already quite familiar with the horse chestnut trees, since they prefer to collect chestnuts from early childhood.

Ash trees are also common in parks and gardens, however, students of this age are not pretty familiar with features of this wood. During experiment, they visited the chosen tree regularly, and they learned about its features in the main directly from the field. They could learn that ash flowers open before the leaves, because the ash is entirely wind-pollinated tree. Flowers are dark purple and a number of butterflies use them as a food source. Both male and female flowers can occur on the same tree, but it is also common to find separately male and female trees. The ash tree has grey twigs with black buds, and students learned to follow opening of the big bud at the end of each twig that contains green leaves, as a first sign of arrived spring.

Practicing this new and interdisciplinary approach in teaching science, Serbian scholars had also the opportunity to make an international web-based networking. The web platform allows them to create own public profile and to share information with peers, which is a fundamental shift in the way they communicate. They were no longer only the end users of the web application, but also active participants. The ability to create and update content led to the collaborative work, and their information became accessible to the other European participants, and beyond.

Important value of this project is a practical applying the IBSE and bridging the gap between formal education and informal learning in elementary schools. There is a widespread belief that extracurricular activities can offer only superficial science knowledge, and that learning of 'real science' in school is exclusively reserved for the classroom activities. However, increased investment in informal learning resources might be a very effective way of improving the public understanding of science. According to research of Falk & Dierking (2010) conducted in America, the average citizen spend less than five percent of their life in classrooms, and the most science knowledge is received outside of school. Modern environment is fulfilled with a wide range of digital resources, internet, television, interactive science museums and community activities such as science festivals and many other scientifically based educational or even entertainment contents.

Working on the “Greenwave”, teachers and pupils successfully applied some of the most important principles of the inquiry-based approach, such as direct experience, as the core of learning science. This unique mass experiment provided the opportunity to students to use the external environment of the school, to communicate and share data from their observations. Significant value of the “Greenwave” was also the multi-disciplinary approach through practical implementation of IBSE and involvement of teachers of different fields. Teamwork, construction and using of measuring instruments, and sharing information with peers were also of particular importance.

IBSE approach increases the interest of students in science. Particularly high level of participation of our scholars in the project also raised a social awareness connected with science, and offered the achievement of scientific literacy for all children. A large number of participants in Serbia reported that the experience from "Greenwave" has increased their understanding of science, and led them towards further inquiries.

Acknowledgement

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References

Bošnjak M, Obadović D 2009. Analiza zastupljenosti izbornog predmeta ruka u testu – otkrivanje sveta u nastavnoj praksi u Zapadnobačkom okrugu. Pedagogija, 1: 145-157.

Bošnjak M, Cvjetićanin S, Branković N, Krivokućin I 2010. Stavovi i iskustva učenika razredne nastave u Srbiji o primeni eksperimenata. Pedagogija, 2: 338-346.

Falk JH, Dierking LD 2010. The 95 Percent Solution. American Scientist, 98: 486-493.

Harlen, W (ed.) 2010. Principles and Big Ideas of Science Education. Hatfield: ASE. Available from www.ase.org.uk in English, from www.fondation-lamap.org in French, and from www.innovec.org.mx (in Spanish).

Hattie JC 2009. Visible Learning: A Synthesis of over 800 Meta-Analyses Relating to Achievement. London & New York: Routledge, Taylor& Francis Group, 379 pp. ISBN 10:0-415-47617-8.

Jokić S 2007. Teaching Science in a primary school: Serbian expiriance with the project Ruka u testu (Hands on, La main à la pâte). Sixth International Conference of the Balkan Physical Union. AIP Conference Proceedings, Vol. 899: 497-498.

Miličić D, Karan-Žnidaršič T, Pavković-Lučić S, Lučić L, Jokić S 2010. Teaching in biological sciences at primary schools in Serbia – an application of the Hands on method. Biotechnology & Biotechnological Equipment, 24: 306-310.

Shymansky JA, Hedges LV, Woodworth G 1990. A reassessment of the effects of inquiry-based science curricula of the 60's on student performance, Journal of Research in Science Teaching, 27(2): 127-144.

Starting Package – Implementing Inquiry-Based Science Education 2010. What is the science inquiry-based approach? The Fibonacci Scientific Committee (www.fibonacci-project.eu).

http://www.fibonacci-project.eu

http://www.fondation-lamap.org/

http://www.greenwave-europe.eu

http://rukautestu.vinca.rs