Zbyněk Vácha, Lukáš Rokos
Czech Republic

The New Educational Review

Integrated Science and Biology Education as Viewed by Czech University Students and their Attitude to Inquiry-Based Scientific Education

DOI: 10.15804/tner.2017.47.1.19

Abstract

The article is focused on the Czech university students' attitudes to integrated science at elementary school and biology at secondary school and their experiences with inquiry-based scientific education (IBSE) of these subjects. Results show students' opinions about teaching methods in nature science education and the direction in which it would be beneficial to aim he future teaching and learning process in Czech educational environment. Our results show that the main reason for integrated science or biology to gain popularity is teacher personality, implementation of field work and usefulness of gained knowledge in everyday life. Respondents' answers revealed that the new educational methods, e.g. IBSE, could have a positive effect on students' approach to natural science subjects.

Keywords: *university student respondent, integrated science and biology education, inquiry-based scientific education*

Introduction

Nature science education situation

Young people's interest in nature science in the last decade has a declining trend. The recession is apparent already in the course of elementary school education (Eilks at al., 2004). According to Janoušková et al. (2008), this is the main reason

why increased attention is devoted to the issue of nature science education. The increased attention is not being addressed only at states' level in their National Education Systems, but also at EU level through the European Commission analyzing the current situation in nature science education. The major cause of the unpopularity of nature science subjects is attributed to frequent use of a scientific paradigm. Characteristic features of such an education comprise clearly given and excessive curriculum structure, and mechanical teaching of facts (Škoda, Doulík, 2009). This educational style results in a situation where Czech students are well able to explain isolated phenomena but lag behind in science-based question solving (Czesaná et al., 2009).

Students' attitudes to integrated science and biology

Research reports on students' attitudes to integrated science and biology examining educational methods in these subjects come solely from abroad. For example, the studies of Trumper (2006) from the Israeli environment and Prokop et al. (2007a, 2007b) from Slovakia, who assessed the effect of factors (gender, age or school grade) on high school students and their attitude to biology. It is evident from the results that respondents assess biology knowledge as important, but fail to see its connection with everyday life. Prokop et al. (2007b) obtained similar results by analogous assessment of elementary school students. As emerged from the results, students count biology among unappealing subjects and find it difficult to realize its contribution to practical life.

Trumper (2006) researched factors influencing students' interest in biology. Based on his results, he suggested adjustments to teaching methods in nature science subjects to make them more attractive. Students should have the opportunity to discover principles and thus satisfy their cognition. Based on their studies, Knight and Wood (2005) and Wilke (2003) ascertained that collaborative teaching or practical teaching are demonstrably more influential on forming students' knowledge compared to frontal instruction. Diversion from the traditional deductive approach to teaching could have a positive impact on students' perception of nature science subjects. As mentioned by Stuchlíková (2010), one of conceptually available didactic trends is widely discussed inquiry-based scientific education (IBSE). During IBSE, the student plays the role of a scientist and builds his knowledge by means of solving given problems in successive steps including stating a hypothesis, selecting appropriate methodology, obtaining and processing results, summarizing results and discussing them (Rochard et al., 2007). Research by Vácha and Petr (2013), focused on the awareness of IBSE among Czech elementary school teachers, implies that half of the respondents have never

encountered IBSE. These results highlight the need for introducing inquiry-based teaching methods in pre-service teacher training in order to further spread IBSE at schools.

Main research goals

The main aim of this study was to find out undergraduate students‘ opinions on integrated science education at elementary schools and biology education at secondary schools, to establish their attitudes to inquiry-based scientific educational methods and to quantitatively generalize the results. Prior to conducting the research, it was assumed that students would consider activating teaching methods to be much more effective and would prefer them. It was expected that students would perceive time consumption and related excessive curriculum structure to be the most frequent limitation to implementing activating methods. Another hypothesis was that students would state a teacher personality to be a significant factor influencing the popularity of integrated science and biology.

Methodology

Data were gathered with the use of a Likert type questionnaire (Skutil, 2011) including open-ended as well as closed-ended scaled questions. The questions focused on demographic data (gender, age, study branch) formed the introductory part of the questionnaire. The remaining items were divided into three sections: 1) university students‘ attitudes to integrated science and biology education, 2) teaching methods used in these subjects and 3) students’ experience with IBSE. The final version of the questionnaire was based on a pilot study tested by 34 university students.

Data were obtained from 245 respondents in total. The questionnaire also included self-depending questions verifying the students’ credibility. 27 respondents with contradicting answers were excluded. The final representative sample comprised 218 respondents (92 males and 126 females). All the respondents were students of the Faculty of Education, the University of South Bohemia. 118 of these respondents attended teacher-training courses (two-branch teacher training in integrated science combined with the English language, Chemistry, Physics, Geography, Physical training, Health education, and Teacher training for elementary schools), whereas 100 respondents studied non-teacher training majors (Nature and environmental education, single-branch Physical training). The respondents’ age ranged from 21 to 25 years.

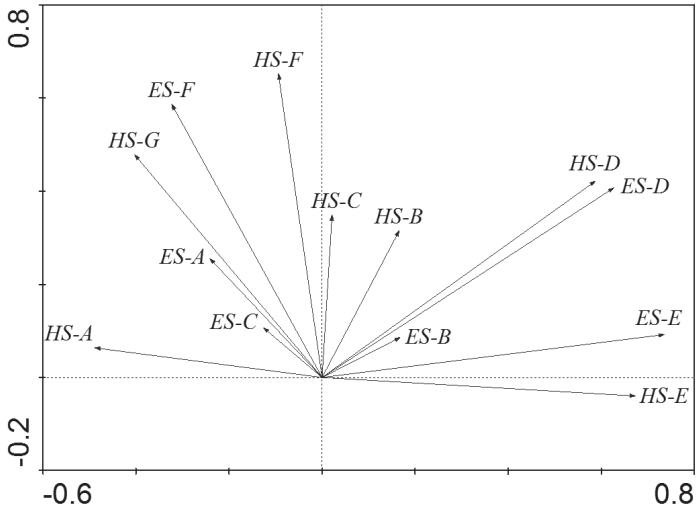
The obtained data were analyzed with the use of statistical methods. For analysis of nominal data a contingency table and Pearson chi-square test were used to analyze the relationship of categorical variables. Data were assessed at the statistical significance level of 0.05. Simultaneously, selected questions were analyzed using a multivariate linear analysis by CANOCO program (TerBraak, Šmilauer, 1998), allowing for testing the pre-stipulated hypotheses in relation to a number of explanatory variables. It facilitates mapping links between dependent and independent variables and enhances their visualization with the use of ordinal axes. Analysis was made with the use of PCA (*principal coordinates analysis*). This method reduces the number of plotted variables by introducing new variables (called main components) in order to intercept the largest amount of volatility of original variables (Hendl, 2009). The main components (=ordinal axes) are therefore mutually uncorrelated hypothetical variables explaining the greatest volatility of original data. The PCA itself does not allow for defining the influence of real explaining variables. This limitation is eliminated by, e.g., RDA (*redundancy analysis*). The limitation is understood as an addition of real variable (significantly influencing analyzed data) to calculated ordinal axes (Lepš, Šmilauer, 2003).

Results and discussion

Integrated science/ biology popularity and unpopularity

The introductory section of the questionnaire was focused on attitudes of undergraduate students to integrated science and biology education during their school attendance. Figure 1 illustrates comparison of responses to question *Why did integrated science and biology belong to your favourite subjects?* What was analyzed were only answers of those respondents who attended biology as an individual high-school subject and who described it to be one of their favourite subjects. The following appeared among the most frequent responses: the teacher's personality, fieldtrips and practicality of gathered information in real life. Difference in popularity of integrated science at elementary school and biology at high school is indicated in answers such as: "I enjoyed experiment demonstrations, and, explained topics were interesting". Responses indicate that the popularity of experiments and laboratory work as well as taught topics increased at high school as compared to elementary school. The research also shows that experiments were incorporated into lessons more frequently at high school and were replacing less attractive teaching methods. This may explain, to some extent, the increasing percentage of popularity of taught subjects at high school.

Figure 1. Reasons for popularity of integrated science at elementary school and biology at high school



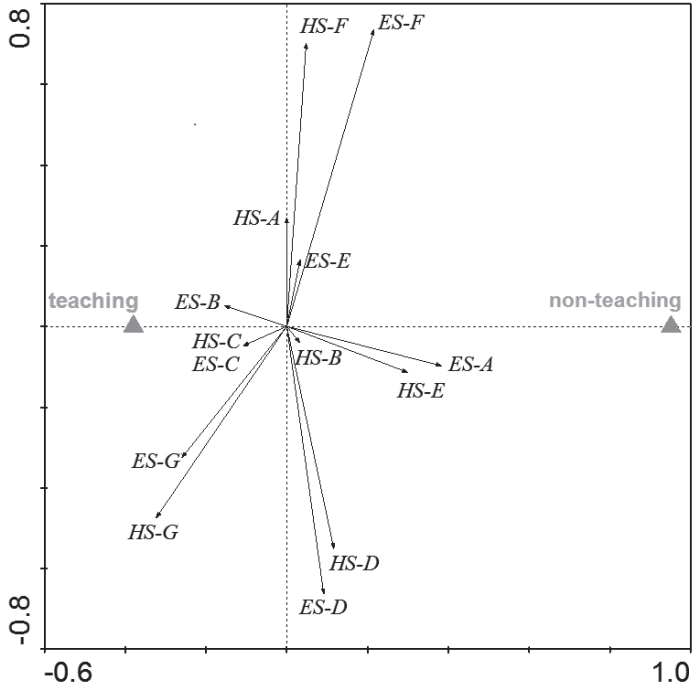
Legend: ES – elementary school; HS – high school; A – attractive topic; B – popularity of laboratory work; C – popularity of experiment demonstration by teacher; D – fieldwork; E – I could use biology knowledge in real life; F – good teacher; G – I was good at the subject

Reasons for the popularity of integrated science and biology were visualized by the PCA method, as none of the explanatory variables (gender, teaching X non-teaching study branch) has a statistically significant influence on respondents' answers. The result of PCA indicates that the popularity of integrated science and biology can be partially explained by the factor of "practical application" (variables E, D) as opposed to simple topic attraction (A) or subject successfulness (G). This first ordinal axis (horizontal) explained almost 20 % of total response variability. The second ordinal axis (vertical), explaining almost 15 % of total variability, could be interpreted as the teacher's influence (F, but partially also D). Overall, the four ordinal axes explained 56% of variability.

The following question (*Why was not integrated science/biology your favoutite subject?*) focused on reasons for the unpopularity of integrated science and biology (Figure 2). Differences are apparent between the answers of the respondents studying teaching and non-teaching majors. The respondents of non-teaching majors stated the teacher's personality to be the main reason for integrated science unpopularity at elementary school and topic difficulty as the reason for biology

unpopularity at high school. The respondents of teaching majors considered oversaturation with facts and unattractiveness of laboratory work to be the main drawbacks of integrated science education. A similar situation arose in answers related to the unpopularity of biology education at high school, where the most frequent answers also included oversaturation with facts and excessive teaching structures.

Figure 2. Reasons for unpopularity of integrated science at elementary school and biology at high school



Legend: teaching – students of teaching majors, non-teaching – students of non-teaching majors; ES – elementary school, HS – high school; A – popular teacher; B – unattractiveness of laboratory work; C – unpopularity of group work; D – unattractive topics; E – difficulty of discussed topic; oversaturation with facts and excessive memorizing; G – other reasons

With inclusion of a real categorical variable (students of teaching majors versus others) in the analysis of integrated science and biology unpopularity, the important factor emerged to be the amount of information (F) with unattractive topics (D) or other reasons (G). The study type of respondents (teaching vs. non-teaching

majors) had a marginally significant effect on their answers ($p = 0.07$; Monte Carlo method), therefore a limited RDA analysis was selected for visualization. However, the axis corresponding to study major explained only 4.7 % of the total variability of responses. The first unlimited axis (vertical), explaining 20.9 % of total variability, complies with the gradient of unattractive topics (D) – oversaturation with facts (F). The first four axes explain in total 56.5 % of variability. An interesting indication shows that while the unpopularity of the teacher at elementary school (ES-A) could influence later choice of a non-teaching study major, the teacher at high school (HS-A) does not have such an effect.

Teaching methods used in integrated science/biology education

The following section of the questionnaire focused on the teaching methods considered by the respondents to be the most beneficial during integrated science and biology education. In the question *Which teaching methods do you consider to be the most beneficial in science education?* the respondents had the choice of four answer options and multiple-choice answers (method sorting was based on the study of Maňák and Švec, 2003): a) skill-practical methods (e.g., direct observation of nature, experiments, etc.), b) illustratively-instructional methods (e.g., observation and demonstration of real objects and phenomena), c) activating methods such as discussion and heuristic method, etc. and d) verbal methods (e.g., lecture, explanation, etc.). The methods that actively engage students in the educational process were considered by the respondents to be the most beneficial teaching methods. The majority of the respondents (110) mentioned practical methods, 104 respondents selected illustratively-instructional methods and 70 respondents stated activating methods. Verbal methods were mentioned to be the least beneficial (41 respondents). Similar results emerged from the research of Rokos et al. (2013), which indicated that the most popular teaching methods and strategies included experiment demonstration, handling real objects and fieldwork. Results of the recent study based on contingency table and Pearson's chi square test indicate that students of elementary school do significantly more fieldwork compared to high school students (Pearsonχ^2: 4.4414, sv = 1, p = 0.0358).

Answers indicate that teachers at both types of schools preferentially used verbal methods. The respondents assume that methods encouraging students to more intense activity were suppressed by teachers due to time constraints and their unwillingness to prepare for such lessons. These results are supported by the findings of Osborne and Dillon (2008), who conducted a similar study of European extent. Their outcomes suggest that verbal teaching methods are still

widely used. The conflict of students' ideas about suitable teaching methods and actually used methods could be viewed as the onset of nature science subjects' unpopularity.

From the above mentioned facts it emerges that education in the field of integrated science and biology is in need of transformation of teaching methods. For successful implementation of such transformation, the curriculum structure must be revised (Korthagen et al., 2012) and also an emphasis needs to be placed on the development of teachers' skills to use methods of scientific research (Škoda, Doulík, 2009). Janoušková et al. (2008) adds that in the current education of nature science subjects it is important to put more emphasis on the comprehension of acquired knowledge and ability to implement it in practical life.

Respondents' experience with IBSE

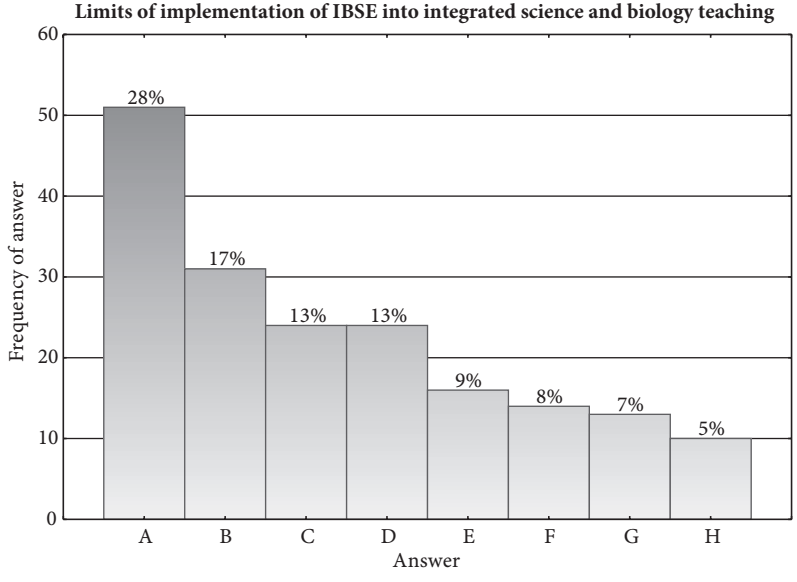
The third section of the questionnaire is aimed at finging out whether respondents have experienced IBSE (*Have you encountered any elements of IBSE in integrated science/biology*), which should, as stated by Eastwell (2009), partially substitute the deductive teaching style. In both, elementary and high school the least frequent response was"often" (ES 9 / HS 11). On the contrary, in the majority of cases the respondents stated that they had "almost never or never" (ES 154 / HS 97) come across elements of IBSE during their elementary and high school attendance. The remaining interviewees stated that they had "at least occasionally" encountered IBSE (ES 55 / HS 50).

Introduction of IBSE elements into education is influenced by specific factors. Individual limitations were characterized by Papáček (2010), who sorted them into four categories: a) limitation at the level of the contents of nature science didactics and methodology, b) limitation at the level of requirements on teachers' educators, c) limitation at the level of teachers' preparedness, d) limitation in the area of school facilities. Schwartz and Crawford (2004) add that another significant element resides in the teacher's experience and ability to choose the pieces of knowledge that are to be built with the use of IBSE. Furthermore, Edelson et al. (1999) extend the list of obstacles by a category of students' motivation and by the insufficient base of students' knowledge and skills.

The aim of this study was to ascertain to what extent our respondents, university students, realize these limitations. In the following question *What do you consider to be the major barrier in implementing IBSE in nature science education?* the research participants could verbally express factors they regard as the greatest obstacles to introducing IBSE to education (Figure 3). This item was incorporated into the questionnaire in order to reflect whether students themselves are aware

of limits to introducing activating teaching methods. The respondents from teaching majors had already attended pedagogical practice placement, therefore their opinion was based on personal experience. Among the most frequent answers there were factors such as time constraint and oversaturated curriculum (51x), insufficient material facilities (31x), pupils' unwillingness to participate (24x), teachers' unwillingness to prepare IBSE (24x), 16 respondents considered IBSE as too exacting, 14 respondents mentioned financial barriers, 13 safety issues and 10 teachers' insufficient qualifications. A large number or respondents (87) did not provide any answer at all. The high number of cases where no answer was provided to this question is probably related to the fact that, as Stuchlíková (2010) mentions, students have difficulty to define the concept of IBSE. Based on this fact, a complex definition of IBSE was at the respondents' disposal during completing the questionnaire.

Figure 3 . Limitations to introducing IBSE to integrated science/biology education



Legend: A – time constraint and oversaturation of curriculum; B – insufficient facilities; C – pupils' unwillingness to participate; D – teachers' unwillingness to prepare lessons with IBSE components; E – teaching aids and materials; F – finances; G – safety; H –teachers' insufficient qualifications

Conclusion

The results of this research point to the significance of teachers' role in education. The teacher's personality itself is the major factor fundamentally influencing the popularity or unpopularity of integrated science and biology. Teaching methods used by the teacher are also essential. University students consider the methods in which students play an active role, such as IBSE, to be the most effective and most popular ones. The analysis of the respondents' answers indicates that activating teaching methods are increasingly utilized in science education, however, classical verbal teaching methods remain to be the prevailing form of education. The greatest obstacle in introducing activating teaching methods is time constraints. The results have thus confirmed the pre-test hypotheses.

Future studies should focus on more frequent use of activating methods in integrated science and biology education as they encourage students to greater independence such as creativity, lay emphasis on the comprehension of the acquired knowledge and its subsequent use in real life. These very trends could make the integrated science and biology education more attractive. This situation should be addressed in teacher training programs at Faculties of Education, where students should be introduced to principles of IBSE within the scope of subject didactics but also of newly emerging subjects reflecting current needs in nature science didactics. For in-service teachers, workshops should be organized, where teachers could give IBSE a tryout, learn to design their own assignments and subsequently implement them into their own teaching. Other options include multi-annual study programs focused on professional IBSE development (eg., Akerson, Hanuscin, 2006).

Acknowledgements
This study originated with the financial support of the Grant Agency of the University of South Bohemia, GAJU 078/2013/S and GAJU 075/2014/S.

References

Akerson, V., Hanuscin, D. (2006). Teaching nature of science throught inquiry. Columbia: University of Missouri. 27 p.

Czesaná, V., Matoušková, Z., Havlíčková, V., Šímová, Z., Kofroňová, O., Lapáček, M., Braňka, J., Žáčková, H. (2009). *Ročenka konkurenceschopnosti České republiky 2007–2008.* Praha. 111 p.

Eastwell, P. (2009). Inquiry learning: Elements of confusion and frustration. *The American biology teacher*, *71*(5), 263–264.

Edelson, D.C, Gordin, D.N., Pea, R.D. (1999). Addressing the challenges of inquiry based

learning through technology and curriculum design. *Journal of the learnig sciences.* 391–450.

Eilks, I., Fischer, H.E., Hammann, M., Neuhaus, B., Petri, J., Ralle, B., Sandmann, A., Schön, L.H., Sumfleth, E., Vogt, H. (2004). Forschungsergebnisse zur Neugestaltung des Unterrichts in Naturwissenschaften. Innsbruck, Wien. 197–215.

Hendl J. (2012). Přehled statistických metod – Analýza a metaanalýza dat. Praha: Portál, 736 s.

Janoušková, S., Novák, J., Maršák, J. (2008). Trendy ve výuce přírodovědných oborů z evropského pohledu. *Acta Facultatis Paedagiogicae Universitatis Trnaviensis*. Trnava. 129–132.

Knight J.K., Wood W.B. (2005). Teaching More by Lecturing Less. *Cell Biology Education*, *4*, 298–310.

Korthagen F., Kessels J., Koster J., Lagerwerf B., Wubbels T. (2012). Jak spojit praxi s teorií: didaktika realistického vzdělávání učitelů. Brno: Paido.290 s.

Lepš, J., Šmilauer, P. (2003). *Multivariate Analysis of Ecological Data using CANOCO*TM. Cambridge: Cambridge University Press, 283 p.

Maňák, J., Švec, V. (2003). Výukové metody. Brno: Paido. 219 p.

Osborne, J., Dillon, J. (2008). Science Education in Europe: Critical reflections.

Dostupná na: http://www.nuffieldfoundation.org/science-educationeurope

Papáček, M. (2010). Limity a šance badatelsky orientovaného vyučování přírodopisu a biologie v České republice. pp. 145–162.

Prokop, P., Tuncer, G., Chudá,J. (2007a). Slovakian Students‘ Attitudes toward Biology. Eurasia Journal of Mathematics, Science & Technology Education, *3*(4), 287–295.

Prokop, P., Prokop, M., Tunnicliffe, S.D. (2007b). Is biology boring? Student attitudes toward biology. Journal of Biological Education, *42*(1), 36–39.

Rochard, M., Csermely, P., Jorde, D., Lenzen, D., Walberg-Henrikson, H., Hermmo, U. (2007). *Science education now: A renewed pedagogy for the future of Europe.* Brussels: European Comission, 22 p.

Rokos, L., Závodská, R., Bílá, M., Řeháčková, L. (2013). The respondent – secondary school and university student and the primary biological education. *International Scientific Publications: Educational Alternatives*, *4*, 334–344.

Schwarz, R.S., Crawford, B.A. (2011). Authentic scientific inquiry as a context for teaching nature of science. Dordrecht. 452 p.

Skutil, M. (2011). Základy pedagogicko-psychologického výzkumu pro studenty učitelství. Praha: Portál.

Stuchlíková, I. (2010). O badatelsky orientovaném vyučování. pp. 129–135. Didaktika biologie v České republice 2010 a badatelsky orientované vyučování (DiBi 2010). České Budějovice. 165 p.

Škoda, J., Doulík, P. (2009). Vývoj paradigmat přírodovědného vzdělávání. *Pedagogická orientace*, *19*(3), 24–44.

Ter Braak, C., Šmilauer, P.V. (1998). CANOCO Reference Manual and User‘s Guide to

Canoco for Windows: Software for Canonical Community Ordination Pages. Ithaca, NY: Microcomputer Power.

Trumper, R. (2006). Factors Affecting Junior High School Students' Interest in Biology. *Science Education International*, *17*, 31–48.

Vácha, Z., Petr, J. (2013). Inquiry based education at primary school throught school gardens. *Journal of International Scientific Publications: Education Alternatives*, *4*, 219–230.

Wilke, R.R. (2003). The effect of active learning on student characteristics in a human physiology course for nonmajors. *Advances in Physiology Education*, *27*(4), 207–223.