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INTRODUCTION OF INQUIRY BASED SCIENCE EDUCATION INTO POLISH SCIENCE CURRICULUM - GENERAL FINDINGS OF TEACHERS' ATTITUDE

WDROŻENIE NAUCZANIA PRZEZ ODKRYWANIE DO POLSKIEJ PODSTAWY PROGRAMOWEJ W ZAKRESIE PRZEDMIOTÓW PRZYRODNICZYCH - BADANIE OPINII NAUCZYCIELI

Abstract: The new Polish science curriculum was launched in the 2008 and currently is being implemented in upper secondary schools. The new general objectives of education, and students' key competences that should be developed during science classes were defined in that document. Presented competences are in line with competences that might be developed by *Inquiry Based Science Education* (IBSE). IBSE is currently a popular instructional method in many countries and it is being strongly promoted by European Union. In the article the role of IBSE in the new Polish science curriculum is described and related to the method of 'Independent Investigation to Acquire Knowledge' that was formerly known in the national pedagogy. The article also presents results of a survey questionnaire that was conducted among Polish science teachers. The aim of the study was to measure the attitude of Polish teachers, pupils and society to IBSE. Based on the results the current position and degree of implementation of IBSE in Polish schools was estimated. Additionally the positive and negative factors affecting the implementation of IBSE were presented.

Keywords: Inquiry Based Science Education (IBSE), reform of science curriculum

Introduction

European Union policy [1] is promoting the development of a knowledge society, to which science education is expected to make a significant contribution. In line with this policy the Rocard report [2] strongly advocated inquiry-based methods in education to increase students' interest in science and boost the number of graduates in science, technical and mathematical studies. As a result many projects promoting inquiry-based methods were begun in recent years and significant changes have been made to national curricula in many European countries. In 2008, the new Polish curriculum for lower and upper secondary school was introduced [3]. Its proposals have been implemented since 2009 in lower

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secondary schools and from 2012 in upper secondary schools. Apart from modernised teaching content, new general objectives of education, and students' key competences were presented in the act. The need to meet these new objectives influences the methods that teachers use [4]. Unfortunately many teachers still think that the aim of chemistry teaching in schools is merely to provide basic subject knowledge and prepare students for final exam [5]. Nevertheless, the school should equip students with skills that enable them to apply what they have learned in practice and to participate fully in cultural, social and professional life [6]. Therefore, a clear difference between chemistry education and chemistry teaching is being outlined. As Soczewka [7] indicated in 1988, chemistry teaching is much narrower concept, focusing on the role of the teacher, rather than on teaching outcomes or forming students' attitudes. Galska-Krajewska [5] distinguishes the following priority goals of chemistry education:

a) acquisition of systematic chemistry knowledge by students,
b) formation of students' chemical culture,
c) development of cognitive skills,
d) developing interests and forming the right attitudes.

A more extensive description of the objectives of education (for upper secondary school) is indicated by Bogdanska-Zarembina [8]:

a) preparation of students for life, in which getting to know nature and care for their own health and that of the environment are respected values,
b) stimulation and development of students' interests in everyday phenomena that are based on chemical reactions,
c) development and nurture of the ability to choose and present interesting information from the mass media, popular science literature, dictionaries, chemical tables, encyclopaedias and textbooks,
d) the ability to perform experiments safely, to use symbolic language and to reason logically using known chemical concepts, as well the results of experiments they have performed,
e) familiarising students with the basics of the structure of matter, and common substances and reactions that can be relatively easily explained,
f) development of the ability to interpret the chemical equations quantitatively (using the mole concept).

The descriptions of the objectives of chemistry education presented above, have much in common with the new Polish curriculum, especially regarding the natural science subjects. The new curriculum advocates methods of student work that are different from the more didactic teaching methods that were previously widely used. The position of the Ministry of National Education, expressed in the correspondence with the Department of Chemical Education Jagiellonian University [9] is as follows: *The core curriculum, despite the empirical education, recommends the use of active teaching methods in the teaching-learning process. In particular, in natural science education, it is recommended that students perform experiments on their own (under the teacher supervision), conducting and recording observations, followed by critical analysis and public presentation of the results. Active methods promoting direct understanding, such as educational trips, educational projects, debates, etc. are also indicated.*

…

Students should have a possibility to observe, study, explore laws and relationships, achieving satisfaction and enjoyment from gaining knowledge on their own in lessons.

…

The scope of the teaching content provides many opportunities to use project methods (especially of research type), practical chemical experiments or other active methods, that enable students to gain information from a variety of sources and to process them in various ways.

A self-contained student's observation is the foundation of the experience, reasoning, analysis and generalisation of phenomena and so experiments play an important role in the accomplishment of the above content.

According to Okoń [10] a teaching method should be regarded as a way of working with students that enables them to acquire knowledge, skills and habits, as well as developing their cognitive abilities and stimulating their interest. On the other hand, Lenarcik [11] describes a teaching method as all projects and organisation procedures that are applied by the teacher in the teaching process, starting from the so-called new material development, through consolidating knowledge and forming habits, to control and evaluate the students' progress. Teaching methods also involve the formation of attitudes and the development of skills in independent learning. The classification of teaching methods presented by W. Okoń in 1987 distinguishes the problem methods of teaching, including learning through discovery [10]. The widely used classification of teaching methods developed by Okoń in 1996 [12] is presented on Figure 1. Discovery is also identified as one of the methods in this classification.

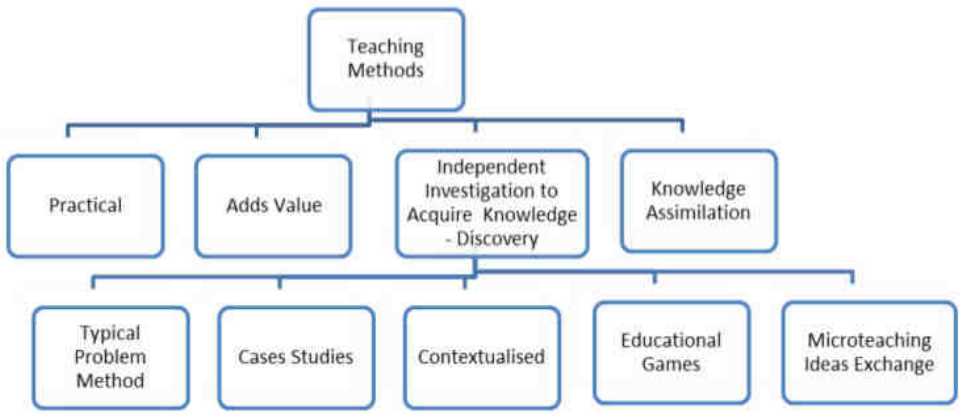

Fig. 1. Classification of teaching methods according to W. Okoń (1996) with a detailed classification of 'Independent Investigation to Acquire Knowledge' [12]

Learning through discovery presented by Okoń may be partially identified with the set of methods known in the literature as IBSE (*Inquiry Based Science Education*). The definition of this method of teaching and learning is attributed to Joseph Schwab and Paul Brandwein [13]. Unfortunately, that there is no specific Polish translation of this expression that is accepted by Polish teachers and educators; this can give rise to problems in teacher training or in preparation of scientific publications. IBSE in Polish can be called as

'Independent Investigation to Acquire Knowledge' or as 'Scientific Method' [14]. The full definition of IBSE is as follows [15]:

Scientific inquiry is the "intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments". Alternatively, the following definition may be used: *Learning through inquiry: Open learning processes require to characterise learning as active discovery in contrast to receptive learning. It does not mean that the teaching content should not be both approachable and understandable. It means that the way of acquiring knowledge and competences should not only be the process of receiving information, but should always be based on discovery* [16].

Therefore, the teaching process based on IBSE should provide problem situations in which the student is a person who defines the research question and tries to find answers based on the scientific inquiry [17]. The principles of constructivism provide the key to understanding the IBSE methodology. As S. Dylak indicates, constructivism (as the theory of knowledge) has two major supports: it is *on the one hand the neurobiological theory of brain function and on the other, pedagogical conceptions, indicating the effectiveness of pedagogical action rules derived from the assumptions of constructivism* [18]. Constructivism stresses the importance of the process by which learners gain new knowledge or improve existing knowledge. For this reason Lunenburg describes learners as constructors of their own knowledge [19], according to their level of understanding; students should not only assimilate knowledge provided by the teacher, but more importantly, construct their own using inquiry-based methods of on teaching and learning. A simplified constructivist inquiry cycle that can be applied in schools was introduced by Llewellyn [20].

The purpose of the research whose results are presented in this article was to establish how Polish teachers find methods based on inquiry. Six areas that may affect the application of IBSE in Polish schools were examined and analyzed:

- The nature of IBSE
- Teachers and IBSE
- Students and IBSE
- School curricula and IBSE
- Public attitudes to IBSE

Methodology of research and research group

The research was based on a questionnaire survey, consisting of 52 values that were presented in random order. The purpose of the survey was to estimate the extent to which the selected values differed in practice from the stated aims of IBSE. Each value may be classified into one of the six categories mentioned above. The differences were measured using a five-point, bipolar scale of the following type: strongly disagree, disagree, not sure, agree, strongly agree. The responses were quantified using the following scale: –2, –1, 0, +1, +2 and the overall results were presented graphically. The lengths of the bars of agreement and disagreement correspond to the overall level of agreement (positive) or disagreement (negative) which were summed independently. The resulting value was divided by the number of participants and multiplied by a scaling factor, that could be

adjusted to set the maximum size of bars in the presentation. An example is shown in Table 1. The answer 'not sure' was not scored, and therefore, it did not influence the length of the bars of agreement and disagreement.

Table 1

Structure of the survey questionnaire

Test value	Scale				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Numerical values assigned	–2	–1	0	1	2
Bars indicating the extent of agreement and disagreement					

The survey was carried out in spring 2011 among the 33 in-service lower secondary and upper secondary school teachers. The teachers surveyed expressed their wish to participate in training connected with the application of IBSE in school practice. Due to the lack of clear Polish name of the method, participants were asked to familiarise themselves with an article on natural science education by inquiry [21] before completing the questionnaire. In the article, the definition and classification of IBSE methods are presented. The questionnaire was completed electronically. The survey was conducted anonymously; however its completion required registration and account activation, which ensured that it could not be completed by people outside from the research group.

Results

Tables 2-7 present the overall results of the survey. The topics were divided into six groups mentioned above and they are presented below in the same order and are followed by an analysis of the results.

Table 2

Results of the questionnaire describing the nature of IBSE

The nature of IBSE	Disagreement	Agreement
IBSE requires more thinking than traditional methods		
IBSE is more suitable for foundation level science courses		
IBSE is more suitable for higher level science courses		
IBSE favours the better students		
IBSE favours the weaker students		
IBSE requires more time than traditional methods		
IBSE requires discussion but there is insufficient time for this in school		
Inquiry methods require longer blocks of time than are not normally available in the school timetable		
Prescribed IBSE exercises defeat the purpose of IBSE		
Laboratory requirements are the same for IBSE and traditional methods		

Table 3

Results of the questionnaire describing the teachers' attitude to IBSE

Teachers and IBSE	Disagreement	Agreement
Teachers are generally convinced of the value of IBSE		
Teachers are generally aware of IBSE		
Inquiry methods are used in most other subjects		
Teachers prefer IBSE methods to traditional methods		
Teachers are not confident in using IBSE methods		
In general teachers have received adequate training in IBSE methods		
Teachers feel that they are not as much in control when students are engaged in inquiry		
IBSE requires more competence on the part of the teachers		
IBSE tasks are often interdisciplinary and can involve topics that are outside the teachers' comfort zone		
Teachers need deeper understanding if they are to facilitate students' engagement with challenging tasks		
There is insufficient cooperation between teachers of different subjects for IBSE		

Table 4

Results of the questionnaire describing the students' attitude to IBSE

Students and IBSE	Disagreement	Agreement
Students are not interested in science		
Students prefer traditional methods		
Where IBSE is the norm students have more positive attitudes to science		
The topics in existing science curricula do not appeal to young people		
Students lack the ability to work independently		
Students lack the confidence to work without explicit instructions		
The laboratory is safer when students are engaged in IBSE		
Students are not confident in using equipment without explicit instructions		
The interdisciplinary nature of IBSE helps students to integrate their learning		
Students require a good foundation to benefit from IBSE		
Students in IBSE classes have a smaller scientific vocabulary		
Students find IBSE too difficult		

Table 5

Results of the questionnaire describing the inclusion of IBSE in existing school curricula

School curricula and IBSE	Disagreement	Agreement
Textbooks are generally suitable for IBSE		
Textbooks are too prescriptive for use in IBSE		
It is difficult to find suitable IBSE topics		
The curriculum is not appropriate for IBSE		
IBSE would require a different kind of curriculum		
It is possible to teach existing science curricula using inquiry methods		

Table 6

Results of the questionnaire describing the evaluation of students' working with IBSE

Assessment and IBSE	Disagreement	Agreement
IBSE leads to better grades in examinations		
New forms of assessment are needed which do not disadvantage IBSE		
Examinations favour students of IBSE		
New forms of assessment are needed which favour IBSE		
It is difficult to compare students' achievement in IBSE because they are engaged in different tasks		
It is easier to assess students' progress using traditional methods		

Table 7

Results of the questionnaire describing the public attitude to IBSE

Public attitude to IBSE	Disagreement	Agreement
Industry's requirements do not favour IBSE		
The system favours didactic methods		
School management supports the implementation of IBSE		
Teacher unions do not favour IBSE		
The school ethos does not favour IBSE		
Parents prefer traditional methods		

Discussion

According to the teachers participating in the study, inquiry-based education requires more intellectual effort than the traditional methods. The situation does not favour weaker students, but is also not regarded as favouring the very good ones. In the teachers' responses, no preferences for applying IBSE at higher or lower levels of teaching of natural science subjects can be observed. However, the teachers agreed that IBSE requires a lot of work and that it is time-consuming, mainly because it requires long discussions. Therefore, IBSE-based teaching requires longer teaching blocks for each subject. Teachers are also clearly convinced that laboratory resources that provide suitable conditions for the traditional teacher presentation of experiments are not sufficient in lessons where IBSE methods are used.

The studied group of teachers is convinced that in the teacher's environment IBSE methods are regarded as very valuable. Unfortunately, small levels of agreement and disagreement were found for the statement: 'Teachers are generally aware of IBSE'; the results suggest that they are not really sure about the definition and applicability of the concept and methods of IBSE. However, there is also a strong belief that IBSE methods are not widely used and respondents agreed that at present school staffs are not adequately prepared for its implementation. As a consequence, teachers do not feel confident when using inquiry methods. The interdisciplinary character of IBSE was found by a significant number of respondents as requiring more competences from average teacher (compared with the present situation), due to their lack of knowledge and skills in other science subjects. The cooperation between teachers of different subjects was unanimously considered to be insufficient for IBSE.

Teachers believe that students are interested in science subjects and that the application of IBSE may enhance those interests. The answers clearly indicate that, according to teachers, students prefer active methods. On the other hand, there is also a strong belief that students do not have appropriate skills for independent laboratory work and that they do not feel confident when working without explicit teacher's instructions. In general the teachers agreed that when IBSE methods were used laboratory work was safer for students, there was greater integration of learning and the students' scientific vocabulary improved.

According to the opinion of the surveyed teachers, textbooks that are available currently in Poland are not suitable for introducing IBSE, as they are too prescriptive; the school syllabuses are also inappropriate for IBSE. On the other hand, the teachers find it possible to follow existing curricula using inquiry methods and they are convinced that it is not difficult to find topics that can be taught in that way.

The teachers believe that the use of IBSE leads to better examination results, although the existing examination questions do not favour IBSE. Hopefully as this situation improves students engaged in IBSE will not be disadvantaged. Teachers' opinions were almost evenly divided on whether or not it was more difficult to assess students' progress using traditional methods.

The vast majority of teachers believe that industry requirements favour the use of methods that are based on science inquiry. Unfortunately, based on the collected responses IBSE is not supported by the school system although the reasons are not clear. A small group of respondents indicated that school management and teacher unions favoured the introduction of IBSE. Its use was regarded as having a positive impact on relations between students and teachers. The teachers were not able to determine how IBSE methods are regarded by parents; the small answer bars indicate that most of them were 'not sure'.

Conclusions

Based on the obtained results it can be stated that teachers have a positive attitude towards IBSE. They feel that scientific inquiry may have a positive impact on teaching outcomes, and that it is interesting and attractive for students, despite the lack of skills associated with laboratory work. The teachers also generally agree that 'Students lack the confidence to work without explicit instructions'. However they do not think that 'Prescribed IBSE exercises defeat the purpose of IBSE'. It shows that teachers identify IBSE with its simpler forms rather than with open inquiry, where all the research process is planned by a student [22]. Furthermore, the lack of agreement (high values of agreement and disagreement bars) on the issue whether 'Students require a good foundation to benefit from IBSE' indicates the different levels of understanding and interpretation of IBSE.

Factors influencing (according to surveyed teachers) in a positive and negative way (supporting and limiting) the introduction of IBSE in schools are presented in Table 8.

Surveyed teachers are convinced that students are interested in natural science. Unfortunately, this statement is not consistent with the results of the ROSE study [23], which revealed that only about 40% of students prefer science subjects to other ones. However, it should be remembered that the ROSE study was performed only in randomly selected schools, whereas the teachers in our tests were already actively involved and were constantly improving their teaching skills.

In general teachers rated their students' practical skills as 'poor', where practical skill is interpreted as the ability to use laboratory equipment. Less attention was paid to the ability to design the whole research process.

Table 8

Positive and negatives factors influencing on the introduction of IBSE to the school practice in Poland

Supporting factors	Limiting factors
• Requirements of external examinations • Motivation to learn • Students' opinions • Curricula • School management • Teacher unions • Industry requirements	• Time requirements • Problems with assessment • Laboratory equipment • It is difficult for weaker students • Poor teachers' preparation • Poor cooperation between teachers • High competences of teachers required • Lack of students' preparation • Lack of proper textbooks • The school system • Syllabuses

The survey also shows that students' positive attitude towards the application of IBSE does not influence the teachers' work. During discussions, teaching staff often compared that situation to the healthcare system, where patients do not in practice have an impact on the treatment process (despite the fact that they may be legally entitled to it). Also the small number of definite answers (different from 'not sure') for the statement 'Parents prefer traditional methods' indicates a lack of information in this area and suggests that parents' opinions are not taken into account. The gap between the teachers' views and the principles of modern education calls for some reflection.

The fact that according to most of respondents 'Teachers do not feel that they are not as much in control when students are engaged in inquiry' is a cause for some optimism. Additionally, the perceived problem of lack of time may be removed by the introduction of the new core curriculum, which reduced the chemistry teaching content in secondary school, as well as in the foundation level of upper secondary schools. Even though, it requires changes in attitudes of the teaching staff, which is a long term process.

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WDROŻENIE NAUCZANIA PRZEZ ODKRYWANIE DO POLSKIEJ PODSTAWY PROGRAMOWEJ W ZAKRESIE PRZEDMIOTÓW PRZYRODNICZYCH - BADANIE OPINII NAUCZYCIELI

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Abstrakt: Nowa podstawa programowa nauczania przedmiotów przyrodniczych w szkołach gimnazjalnych i ponadgimnazjalnych została przedstawiona w 2008 roku, a jej założenia są obecnie wdrażane do szkół ponadgimnazjalnych. Przedstawiono w niej nowe cele ogólne nauczania oraz kompetencje kluczowe, które powinny zostać rozwinięte poprzez nauczanie przedmiotów przyrodniczych. Przedstawione kompetencje są zgodne z kompetencjami, które mogą być kształtowane poprzez zastosowanie tak zwanego nauczania przez odkrywanie/dociekanie naukowe - IBSE (ang. Inquiry Based Science Education). IBSE jest popularną strategią nauczania w wielu krajach europejskich, a jej stosowanie jest silnie promowane przez Unię Europejską. W artykule przedstawiono rolę, jaką IBSE może odgrywać w nauczaniu opartym na nowej podstawie programowej i omówiono tę strategię w odniesieniu do metod opartych na samodzielnym zdobywaniu wiedzy, które były wcześniej opisywane w polskiej literaturze pedagogicznej. W artykule zaprezentowano również wyniki badania ankietowego, którego celem była ocena stosunku nauczycieli, społeczeństwa oraz uczniów do IBSE. Na podstawie otrzymanych wyników oszacowano, jaki jest aktualny stopień wykorzystania IBSE w polskich szkołach oraz zestawiono pozytywne i negatywne czynniki wpływające na wdrażanie IBSE do szkół.

Słowa kluczowe: nauczanie przez odkrywanie, reforma edukacji, nowa podstawa programowa