How does IBSE affect physics teaching?

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Abstract

The paper presents an assessment of the impact of teaching physics using the Inquiry Based Science Education (IBSE) method on the level of competence and knowledge of primary school students in Poland (second educational stage). The method is based on the teacher-inspired teamwork of students to solve experimental physical problems. This results in strengthening students' inquisitiveness, daring to hypothesize, analytical skills and critical thinking. Educational progress was observed during two years of work with two classes of children aged 12-14 years (classes VII – VIII in the Polish primary education system). The students' level of knowledge was assessed through tests conducted at the beginning and end of the teaching cycle, and the results were analyzed using statistical data analysis. The analysis revealed a significant increase in students' interest in physics, strengthening skills and independence in performing experiments, and increasing cognitive initiative. Importantly, the work on physics classes – positively influenced the involvement of students in the process of teaching other subjects.

Keywords: IBSE, teaching physics, primary school, conducting interesting lessons and students' interest in physics.

INTRODUCTION

In the modern world, knowledge seems to be easily accessible, because we have almost universal access to the Internet, which seems to contain an infinite amount of information. However, the availability of information does not necessarily lead to knowledge, as it is not only a collection of facts, but also an ability to analyse them and to draw conclusions. For this, imagination and intuition are still necessary, and we will not find these on the Internet.

What is knowledge? Epistemology, a branch of philosophy that deals with the nature, sources and limitations of human knowledge, tries to answer this question. The name comes from the Greek word episteme, which means certain and proven knowledge, thus different from the common belief called in Greek doksa. So how does knowledge differ from opinion? The classic definition of knowledge was given by Plato in the dialogue Teajtet, where Socrates, in a conversation with Teajtet, concludes that knowledge is a true, justified belief (Chappell, 2005). The following three elements of knowledge are distinguished in this concept: beliefs, logical judgments, and justification. To understand an issue, we must not only gather the facts that describe it, but also properly grasp the relationships that exist between them. In turn, to understand the causes of events it is not enough to know that the event occurred at a specific time, but also to be aware of the relationship between events. It is necessary to answer not only the question: what happened, but also 'why?', 'how?' and 'what was the result?'.

We must learn how to act appropriately in the process of acquiring knowledge, bearing in mind that knowledge is passed on from generation to generation and therefore requires the gathering and cooperation of many people. If we could rely solely on the information we gathered ourselves, we would only know a fraction of what we know now. It's from other people's assurances that I know if my test results are good. From trivia to information of great importance, we depend on each other. It would seem, therefore, that we can rely on the opinion of an expert in the field in order to be convinced that the information obtained is true. However, we should always act critically and verify the sources of information.

The path to knowledge leads through the school, but the school should not only pass on knowledge, but above all develop in the students the right habits to act on the way to its acquisition, accumulation and creative transformation. It should also develop in students the ability and habit of cooperation in this activity. Inquiry Based Learning (IBL) method (Gettier, 1963; Lesny, 2018; Sokołowska, 2018; Bernard et al., 2012) is one of the methods for shaping students' correct learning habits. An important element of this strategy can be considered scientific inquiry in the field of natural sciences, which is referred to as Inquiry Based Science Education (IBSE).

Elements of the IBL method appeared in the works of Jean Piaget [6]. According to him, the main goal of education is to educate people capable of innovation, not just to repeat what

other generations have contributed. The school is supposed to let people into the world who are creators, inventors and explorers. The second goal of education is to train minds to criticize and validate, and not necessarily accept, everything they receive.

The genesis of IBL also finds its source in the works of Lev Vygotsky (1985), who promoted "mutual teaching". Cooperation between the teacher and the students makes it easier to remember and practice skills such as: prediction, explanation, asking questions. The joint work of the teacher with the pupils and with each other, carried out on the basis of reciprocity, creates a kind of scaffolding that facilitates the acquisition of knowledge and creates behavioural habits (the next stage of learning is based on the previously acquired knowledge). The person creating the scaffolding can be a peer, a teacher, or even a parent. The term scaffolding is often used in literature, but it should be remembered that Vygotsky (1978) never used the word in his writing, and it was first used by Wood, Bruner and Ross (1976). They defined it as support and supervision by a more capable or competent person (tutor or parent) to perform a task that the child would not be able to perform on his or her own. In turn, Dewey (2006) pointed out that proper education is favored by situations when a student's previous experience helps to face others and thus creates a positive continuity of experiences that strengthens the effects of education.

The above objectives and teaching practices are embodied in the IBSE idea. IBSE can therefore be considered, as defined by Vicenty Okoń (1998), as a method of teaching, since it is 'a way of working between the teacher and the pupils, enabling the educational objectives to be achieved, in other words, a tried-and-tested arrangement of the activities of the teachers and the pupils carried out consciously in order to bring about complex changes in the pupils' personalities'. One of the important goals of introducing IBSE to science didactics is to bring school teaching closer to the real process of scientific knowledge. Students almost independently, in cooperation with the teacher, acquire the knowledge and skills to critically formulate thoughts and cognitive goals. Thanks to this, they improve their competences:

- Learn critical, creative thinking and self-assessment,
- Learn to select and analyse data,
- Learn science more effectively,
- Learn the elements of scientific work,
- Enrich social skills (communication, trust, cooperation).

RESEARCH METHODOLOGY

In order to obtain an objective assessment of the effectiveness of the IBSE method in physics teaching, a statistical comparative analysis of the semester scores and the results of the tests checking knowledge before the start and after the end of the work with this method was carried

out. This made it possible to compare the acquired knowledge and skills of IBSE students with the results of students taught in a traditional way, based on the transfer of information and work of the students with the textbook and on the presentation of the experiences by the teacher, but with little involvement of the students in the experiment.

Teaching in both groups concerned the same issues from the core curriculum of physics in primary school in Poland. During two years of work with both groups of students, simple physical experiments were performed, which were related to the currently discussed issues. As mentioned earlier, in the IBSE group the students themselves prepared and carried out the experiments planned by the teachers, while in the control group the experiments were carried out and discussed by the teacher. Classes were conducted in an open format (with the possibility of participation of other interested teachers) and were recorded, with the consent of the parents, in order to better analyse pupils' behaviour.

The knowledge test consisted of 20 questions in physics and included questions from science subjects taught in younger classes (grades I-VI). The student answered the same questions before the start of the teaching cycle (pre-test) and after completion (post-test) and could obtain a maximum of 50 points. The test results were scored on a scale of 1-6, with 1 being the lowest score and 6 the highest.

IBM SPSS Statistics 27 was used for statistical analysis of learning outcomes. The analysis of basic descriptive statistics was performed together with the Shapiro-Wolf test, as well as the Student t test for dependent samples. The significance level of the tests was $\alpha = 0,05$.

RESULTS

Basic descriptive statistics with Shapiro-Wolf test was utilized in this study. In the first step, the results of tests to check the acquired knowledge (pre- and post-test) were subjected to statistical analysis. The analysis of descriptive statistics was performed and the normality of the distribution was checked using the Shapiro-Wilk test. This was done separately for the class where the IBSE method was used and for the class where the IBSE method was not implemented. The mean scores of students at baseline were similar in both groups (IBSE: M = 3. 53, Me = 3. 00, SD = 1. 02, Sk. =0. 10, W = 0. 88, p=0. 024 and without IBSE: M = 3. 59, Me = 3. 00, SD = 1. 18, Sk. =0. 41, W = 0. 92, p=0. 123), the same can be observed for the pre-test (IBSE: M = 54. 68, Me = 55. 00, SD = 9. 71, Sk. =0. 47, W=0. 96, p=0. 479 and without IBSE: M=52. 65, Me=50. 00, SD=6. 7, Sk. =1. 45, W=0. 82, p=0. 003).

The results of the analyses are presented in Tables 1 and graphically presented in Graphs.

Table 1. *Basic descriptive statistics of the studied variables together with the Shapiro-Wilk test – for students with implemented IBSE*

Class results of students with implemented IBSE (N =19)										
Awards For The Semester (Min 1, Max 6)	*M*	*Me*	*SD*	*Sk.*	*Kurt.*	*Min.*	*Max.*	*Stretch*	*W*	*p*
Class 7 - I Semester	3,53	3,00	1,02	0,10	-1,00	2,00	5,00	3	0,88	0,024
Class 7 - II Semester	4,16	4,00	1,34	-0,32	-1,01	2,00	6,00	4	0,90	0,054
Class 8 - I Semester	4,05	4,00	1,03	-0,80	-0,38	2,00	5,00	3	0,82	0,002
Class 8 - II Semester	4,58	5,00	1,30	-0,78	-0,31	2,00	6,00	4	0,87	0,012
Test Results (Min 0, Max 60)	*M*	*Me*	*SD*	*Sk.*	*Kurt.*	*Min.*	*Max.*	*Stretch*	*W*	*p*
Pre-Test - Class 7	54,68	55,00	9,71	0,47	-0,03	39,00	77,00	38	0,96	0,479
Post-Test - Class 8	67,32	67,00	13,04	0,29	-0,57	44,00	90,05	46	0,96	0,645
Class Results Without IBSE (N =17)										
Awards For The Semester (Min 1, Max 6)	*M*	*Me*	*SD*	*Sk.*	*Kurt.*	*Min.*	*Max.*	*Stretch*	*W*	*p*
Class 7 - I Semester	3,59	3,00	1,18	0,41	-0,53	2,00	6,00	4	0,92	0,123
Class 7 - II Semester	4,29	5,00	1,21	-0,64	-0,30	2,00	6,00	4	0,89	0,045
Class 8 - I Semester	3,53	4,00	1,23	0,61	0,20	2,00	6,00	4	0,86	0,017
Class 8 - II Semester	3,41	4,00	1,28	0,32	-0,85	2,00	6,00	4	0,87	0,020
Test Results (Min 0, Max 60)	*M*	*Me*	*SD*	*Sk.*	*Kurt.*	*Min.*	*Max.*	*Stretch*	*W*	*p*
Pre-Test - Klasa 7	52,65	50,00	6,70	1,45	1,70	46,00	68,00	22	0,82	0,003
Post-Test - Klasa 8	55,82	53,00	8,00	1,70	2,84	49,00	78,00	29	0,78	0,001

**M – average; Me – median; SD – standard deviation; Sk. – skewness; Kurt. – kurtosis; Min and Max. – the lowest and highest distribution value; Stretch – the difference between the maximum and minimum value; W – the result of the Shapiro-Wolf test; p – relevance of the S-W test*

The distribution of grades differs from the normal distribution, therefore the result of the Shapiro-Wilk test for the results of students with implemented IBSE turned out to be statistically significant for grades in grade 7 (1st semester) as well as grades in grade 8 (both semesters). For students without implemented IBSE, the normal distribution test proved to be

relevant for grades of students in grade 7 (second semester), grade 8 (both semesters), as well as pre- and post-test results.

Impact Of IBSE On School Grades And Knowledge

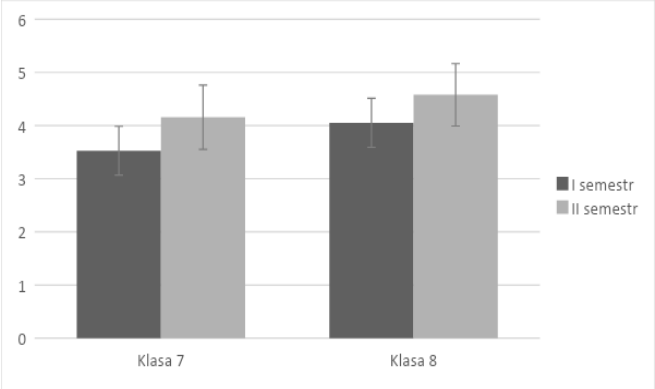
In order to check whether the implementation of IBSE had an impact on school grades and students' knowledge, the results before and after the educational intervention were compared using the Student's t-test for dependent and independent tests. First, the change in grades between semesters 7 and 8 was analyzed for the IBSE group and the non-IBSE group (Table 2, 3, Figure 1, 2)

Table 2. *Comparison Of School Grades Between Semesters In Seventh And Eighth Grade – Implemented IBSE*

	I Semester (*N* = 19)		**II Semester (*N* = 19)**				**95% *CI***		
Grades Per Semester (N-Number Of Groups)	*M*	*SD*	*M*	*SD*	*t*	*p*	*LL*	*UL*	*d* Cohena
Class 7 (19)	3,53	1,02	4,16	1,34	-3,31	**0,003**	-1,03	-0,23	0,76
Class 8 (19)	4,05	1,03	4,58	1,30	-3,75	**0,001**	-0,82	-0,23	0,86

**M – average; SD – standard deviation;*

Figure 1. *Average Grades In The First And Second Semesters For Seventh And Eighth Grades – Implemented IBSE*



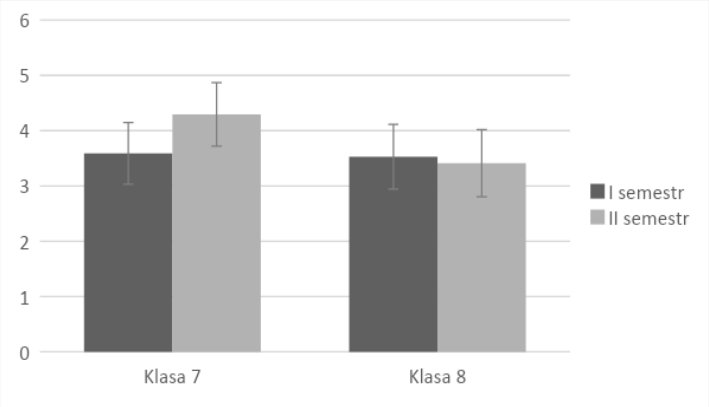
Looking at the table and graph, we can see that in the second semester these scores improved. The above results suggest that the IBSE method is effective in acquiring knowledge.

The results are statistically significant as they are less than 0. 05. The table shows that the Cohen coefficient indicating the strength of the effect is large.

Table 3. *Comparison Of School Grades Between Semesters In Seventh And Eighth Grade – Non IBSE*

	I Semester (*N* = 17)		**II Semester (*N* = 17)**				**95% *CI***		
Grades Per Semester (N-Number Of Groups)	*M*	*SD*	*M*	*SD*	*t*	*p*	*LL*	*UL*	*d* Cohena
Class 7 (17)	3,59	1,18	4,29	1,21	-4,95	**<0,001**	-1,01	-0,40	1,20
Class 8 (17)	3,53	1,23	3,41	1,28	0,62	0,543	-0,28	0,52	0,15

Figure 2. *Comparison of grades in the first and second semester for grades 7 and 8 – class without IBSE*



The result of the analysis proved to be statistically significant for comparing the scores obtained in two semesters in both grades (seventh and eighth) in the group of children with implemented IBSE. It turns out that after the procedures, both the seventh and eighth grades were better at the end of the semester compared to the measurements at the beginning of the semester. This indicates an improvement in assessments as a result of the impact carried out.

In the group of children without IBSE, the analysis turned out to be relevant only for comparing grades between semesters in the seventh grade. By the end of the semester, seventh

grade students had better grades. No statistically significant results were observed in the eighth grade, although an analysis of the averages indicates a deterioration of grades at the end of the semester in this group of children. This may be related to preparing students for eighth grade exams. This has not been observed in IBSE students, which may be associated with higher motivation to study.

An analysis was then carried out, comparing the results obtained in the pre-test (conducted in the seventh grade) and the post-test (conducted in the eighth grade) by students with the IBSE method implemented and students without such implementation. In addition, the results obtained at the end of the eighth grade (post-test) were compared between the IBSE and non-IBSE groups (Tables 4,5,6 Figures 3, 4, 5).

Table 4. *Comparison Of Pre-Test And Post-Test Proficiency Test Results – IBSE Group*

	Pre-test (*N* = 19)		**Post-test (*N* = 19)**				**95% *CI***		
	M	*SD*	*M*	*SD*	*t*	*p*	*LL*	*UL*	*d* Cohena
Skills (17)	54,68	9,71	67,32	13,04	-10,51	**<0,001**	-15,16	-10,11	2,41

Figure 3. *Comparison Of The Results Of The Pre-Test And Post-Test Proficiency Test – Class With IBSE*

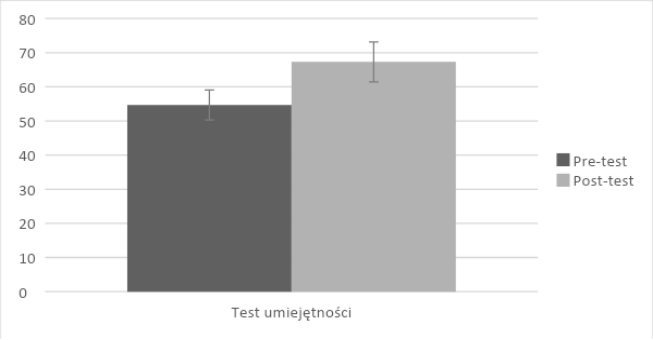
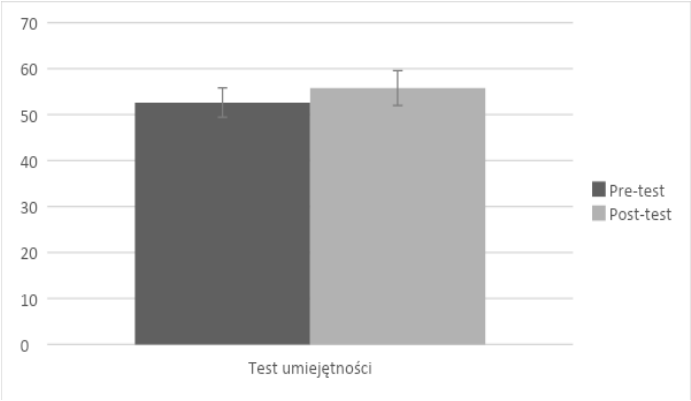


Table 5*. Comparison Of The Results Of The Pre-Test And The Post-Test – Group Without IBSE*

	Pre-test (*N* = 17)		**Post-test (*N* = 17)**				**95% *CI***		
	M	*SD*	*M*	*SD*	*t*	*p*	*LL*	*UL*	*d* Cohena
Skills (17)	52,65	6,70	55,82	8,00	-5,99	**<0,001**	-4,30	-2,05	1,45

Figure 4*. Comparison Of The Results Of The Pre-Test And Post-Test Proficiency Test – Class Without IBSE*

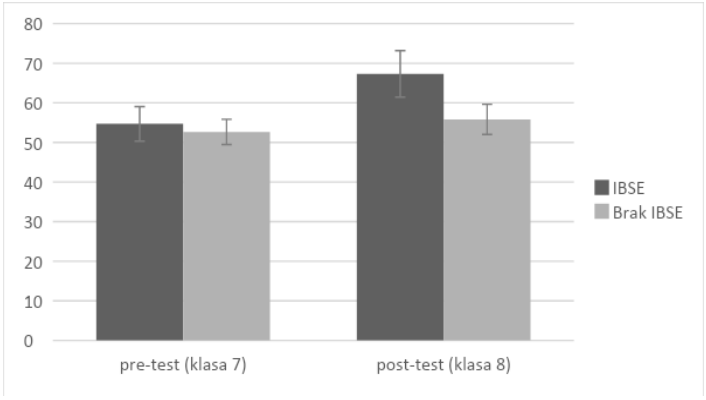


In the post test, the score was almost 12 points higher for the IBSE group. The power of the effect is very large. Dependency in the group without IBSE is only 2 points higher. Children in both groups acquired the required knowledge, but in the IBSE group they acquired knowledge more effectively. In the test the results are not important, there was no impact, the results were comparable as expected. Posttest difference very large. IBSE children had much better results. The dependence is statistically significant and the effect is strong. All results point to greater effectiveness of the IBSE method in physics teaching compared to traditional (feed) teaching. The test has been successful and the action is effective.

Table 6. *Comparison Of The Results Of The Pre-Test And Post-Test According To The Group*

	IBSE (*n* = 19)		**non IBSE (*n* = 17)**		**95% *CI***				
	M	*SD*	*M*	*SD*	*t*	*p*	*LL*	*UL*	*d* Cohena
Pre-Test (Class 7)	54,68	9,71	52,65	6,70	0,72	0,474	-3,68	7,76	0,24
Post-Test (Class 8)	67,32	13,04	55,82	8,00	3,14	**0,003**	4,06	18,93	1,05

Figure 5*. Comparison Of The Results Of The Pre-Test And Post-Test According To The Group*



It should be noted that the groups started from the same stage of knowledge and skills, as shown in the graph. The result of the analysis proved to be statistically significant for comparing the results of the aptitude test in the seventh and eighth grades both in the group of children with implemented IBSE and in the group of children without this effect. It turns out that in the eighth grade (post-test) children performed better than in the seventh grade (pre-test), both when the work was carried out using the IBSE method and when the work was carried out without the implementation of the IBSE method.

The comparison of the group of children with IBSE and without IBSE showed a significant difference in the measurement made in the post-test (in the eighth grade). Children with IBSE scored significantly better in the post-test than children without the implementation of this method, which indicates its effectiveness. In the pre-test, no differences were observed between the two groups, which indicates that before the implementation of IBSE both groups had the same level of knowledge and skills.

DISCUSSION

One year after graduating from primary school, a survey was conducted among graduates who participated in IBSE classes. They were asked: Have you noticed the differences between teaching physics at primary school and the school you are currently studying at? Please expand your statement.

Four students responded to the survey and their opinions are set out below:

- *"No, here and here I learned a lot of thanks to the loose approach of the teacher"*
- *"I noticed a big difference. In primary school, the teacher was able to present the material and encourage students who were not interested in the lesson in any way. She could explain even the most difficult subjects. There were many interesting experiences. On the other hand, the teacher in the current school does not help the students to understand the subject being studied but requires it to be understood. He does not explain too well and does not even try in any way. He has no experience and his lessons are boring and uninteresting. "*
- *"In 7th and 8th grade physics was more friendly to students and the teacher was 11/10"*
- *"Physics classes are interesting in both primary and current school, but I would like to have experiments or quizzes like 'Kahoot' in my current school".*

In order to assess the students' acquired skills and change their attitudes towards teaching, I also asked for the opinion of teachers of other subjects, teachers who worked in both classes studied more fully. The following are some of the teachers' opinions as a result of their observations:

- *"The IBSE students showed greater learning ability. They understood commands more easily"*

- *"Pupils worked alone in a group and individually with little help from the teacher, and in the classroom without IBSE as instructed by the teacher"*
- *"The teacher in both classes motivates students to learn through the preparation of teaching aids, the opportunity to experiment. In IBSE class, students easily used prepared teaching aids and designed experiences, in the second class, students more often used the help of the teacher."*
- *"An interesting lesson, IBSE students are more independent, using ICT methods in class, they are free to use tablets and phones for evaluation in MENTI or Kahoot test. You can see that the class has more freedom to design experiences and even students with learning difficulties are willing to work and come up with relevant conclusions. "*

It should be noted that all teachers have been able to participate in IBSE open classes, which will probably contribute to the promotion of IBSE teaching.

SUMMARY

The analysis of student ratings, the opinions of students and teachers entitle me to state that thanks to the IBSE method it is possible to strengthen the curiosity of students and significantly stimulate their activity in the lessons, thus increasing cognitive abilities and the desire to independently analyze natural phenomena.

My experience so far shows that conducting classes using the IBSE method contributes to the activation of students and makes it easier for them to assimilate knowledge and thus start to like physics. According to my research and others, the IBSE method helps students to better understand the laws of nature and scientific concepts, teaches criticism and better prepares them to undertake independent analysis of phenomena occurring in the surrounding world. Importantly, it also contributes to the development of the teacher (inspiring dialogue, creating a favorable atmosphere in the classroom, formative assessment). It should also be mentioned that my observations also show that the IBSE eliminates gender stereotyping in science subjects and refutes the stereotype that girls are less likely to learn physics. All students are equal participants in the activities and inspire each other as they explore and solve physical problems. The current Programme framework contains many postulates in line with IBSE.

REFERENCES

Bernard, P., Białas, A., Broś, P., Ellermeijer, T., Kędzierska, E., Krzeczkowska, M., & Szostak, E. (2012). Podstawy metodologii IBSE. https://ruj.uj.edu.pl/xmlui/bitstream/handle/item/59909/bernard_bialas_bros_et-al_podstawy_metodologii_ibse_2012.pdf?sequence=1&isAllowed=y

Chappell, S. G. (2005). Plato on Knowledge in the Theaetetus.

Dewey, J. (2006). School and the child , tłum. H. Błeszyńska, Warszawa, ŻAK Wydawnictwo Akademickie. *The Child and the Curriculum.*

Edmund L. G. (1963). Is Justified True Belief Knowledge? *Analysis* (23), 121-23.

Lesny, A. (2018). Czym jest metoda IBSE?. http://alesny.pl/czym-jest-metoda-ibse/

Piaget, J. (1985). Building up reality in a child.

Sokołowska, D. (2018). Podstawy IBSE. http://www.ack.fais.uj.edu.pl/documents/97137412/c08fb2f1-d5c9-4067-acce-f41c810673e3

Vygotsky, L. (1978), Interaction between learning and development. *Readings On The Development Of Children,* 23(3), 34-41.

Wood, D., Bruner, J. S., & Ross, G. (1976), The Role Of Tutoring In Problem Solving, *Journal Of Child Psychology And Psychiatry*, 17(2), 89-100.

W. Okoń, W. (1998). *Introduction To General Didactics*. PWN Warszawa.