LEARNING BY BEING IN SCIENCE EDUCATION

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Abstract. In the present work, the educational paradigms of memorization, active learning, inquiry-based science education are analyzed and the impact factors for different didactic strategies used within these paradigms are presented. All impact factors are compared to the one of face-to-face or conventional teaching. An important conclusion is that collaborative learning in small groups increases the academic success of students by about 25% compared to conventional teaching. The didactic concept of Learning by Being (LBB) which is based on the assumption of cognitive objectives by students, metacognition, permanent and mutual feedback is described. The teacher's role within the LBB concept is analyzed and the teacher's actions are shown within the students' independent research activity called guided self-scaffolding. It is shown that the basic role of the teacher in LBB is the formation and development of students' metacognition.

Keywords: inquiry-based science education, learning by being, assumption of cognitive goals, metacognition.

Rezumat. În lucrarea de față sunt analizate paradigmele educaționale ale memorării, învățării active, învățării prin cercetare și sunt prezentați factorii de impact pentru diferite strategii didactice utilizate în cadrul acestor paradigme. Toți factorii de impact sunt comparați cu cel al predării frontale sau convenționale. O concluzie importantă este că învățarea prin colaborare în grupuri mici crește succesul academic al studenților cu aproximativ 25% comparativ cu predarea convențională. Este descris conceptul didactic de *Learning by Being (LBB)* care se bazează pe asumarea de către elevi a obiectivelor cognitive, metacogniție, feedback permanent și reciproc. Este analizat rolul profesorului în cadrul conceptului LBB și sunt prezentate acțiunile lui în cadrul activității de cercetare independentă a elevilor numită auto-eșafodaj ghidat. În articol se arată că rolul de bază al profesorului în cadrul LBB este formarea și dezvoltarea metacogniției elevilor.

Cuvinte-cheie: învățarea științelor prin cercetare, învățarea prin a fi, asumarea obiectivelor cognitive, metacogniție.

Theoretical framework

In the context of the knowledge-based society, the concern for the problem of low motivation and low interest of students in studying science and especially physics is a constant in science education. For example, in the ERIC database for the search term "Motivation" for the period from 2020 to the present we find 12962 references of which 6293 are for the school level, the others being for college, university, adult education, or kindergarten [1]. Research also shows that, with the advancement of school studies over time, students' interest in physics also decreases, the subject becoming increasingly boring from year to year [2]. From the point of view of physics teachers, among the main factors that influence students' interest in physics are the following ones: the insignificant demand for physicists on the labor market, physics is difficult and too abstract for most students, physics is perceived as an object of study only for boys [3]. Extra- and co-curricular activities together with laboratory work and/or inquiry projects seem to be the solution to increasing understanding and interest in physics [4]. For example, the use of the Inquiry Based Science Education (IBSE) method, when solving experimental physics problems in grades VII-VIII led to the strengthening of curiosity and independence in conducting the experiment, the development of the ability to formulate hypotheses, increase of critical thinking skills and the increase of educational progress after two years of applying the method [5].

The course of educational paradigms over time reflects, in fact, the permanent search for teaching methods that place the student, irreversibly, in the area of motivation and interest. In this communication we will try to describe the basic properties of an eminently constructivist didactic concept, called Learning by Being, which enriches the IBSE concept with students' attitude and intrinsic motivation [6]. To be more explicit, the phrase "Learning by Being" should be extended to the form "Learning by Being a Real Learner". In other words, here we will talk about how the qualities of a student dedicated to learning can be formed.

Historically, the first educational paradigm is the one of memorization. Even in its most simplistic, mechanical form, the memorization of definitions, formulas, or physical meaning of quantities is not necessarily a bad thing. Because as long as memorization is transformed from superficial to deep one, and subsequently to conceptual understanding, the use of memorization-based learning techniques should be welcomed. For example, among ten learning techniques analysed by Gregory Donoghue and John Hattie from Science of Learning Research Center in University of Melbourne in their article in Frontiers in Education, *mnemonics* is a learning strategy with a low efficiency and has one the lowest impact factor (IF) equal to 0,33 [7]. For comparison, the second least effective learning technique is *re-reading* with IF=0,47 which is a little bit higher than *frontal* or *conventional teaching* with IF=0,40. We have to say, that hereinafter all impact factors (IF) we will compare permanently with frontal teaching: we will use IF=0,40 as benchmark level – anything below this level will be considered to have a negative impact on academic success of students. Also, summarization with IF=0,44 could be considered a memorization technique. Besides these numbers, we should clearly emphasize that the impact of one or another learning strategy depends on many other important student-related factors: motivation, interest, attitude, etc. In addition, these numbers can vary from teacher to teacher, as well as from one class to another. In other words, the IF of one or another strategy in this short communication must be viewed first of all from qualitative point of view.

The next step in the evolution of educational paradigms is the one of Learning by Doing, or Active Learning. There are many strategies for active learning and teaching. The impact factor on students' academic success for many of them was calculated in the well-known book of John Hattie [8]. These strategies are divided into two categories: learning strategies and teaching strategies. The difference between them is that in the case of learning strategies namely the student is the subject of the action, responsible for his/her learning outcomes, and in the case of teaching strategies the teacher is the subject and students – the object of the action. For example, ludic education or gamified education has an IF=0,35 which is lower than benchmark level of frontal teaching with IF = 0,40. But when we introduce student – student and student – teacher interaction, the IF on academic success for ludic interactive activities increases up to 0,50 it means with 25% compared with frontal teaching. So, the first conclusion comes:

C1 "An interactive game is a little bit better than frontal teaching in a quiet class".

Also, collaborative learning within small groups has an impact factor that cannot be neglected IF = 0,55. In such a way the second and third conclusions come:

C2 "Learning within small groups is better than individualistic learning" and

C3 "The presence of real cooperation between students enhances their academic success with 25%".

In other words: academic success depends on number of interactions in classroom. Thus, the qualitative leap from one paradigm to another is ensured by the increase in the number of interactions in the class. In this way the transition from the linear paradigm of doing to the one of understanding, requires first of all a higher degree of students' involvement. In this sense the article of American researchers Lei Bao and Kathleen Koenig published in Springer [9] presents the strategies for deep learning in order to form 21-Century skills (it means, first of all high-reasoning skills) and the idea is to: a) increase the number of connections or interactions in class, or to promote the growth of communication, b) to obtain scientific reasoning within inquiry labs. For example, the most known strategy leading to understanding is Inquiry-Based Science Education (IBSE) with an IF=0,77 which is almost double compared to the usual teaching. IBSE are actually research-based collaborative projects. Good examples of IBSE or "la maine a la pate" projects are presented in the communication of Serbian professor Stevan Jokici. Such a project or learning unit may last few lessons. Within a single IBSE project the students will focus on three, up to four big scientific ideas (BSI). An example of BSI for the chapter "Oscillations and Mechanical Waves" in the 8^{th} grade is: wave length, frequency, period.

Research question

Thus, having broadly described the paradigms of memorization, active learning and learning through research, we arrive at the first research question: "What would be the didactic concept, in which the central role would be: the cognitive effort of the students, the assumption of the learning objectives and the students' understanding of their own learning?"

Also we should identify possible answers to the second research question: "What should be the teacher's role within the didactic concept which is focused on students' intrinsic assumption of cognitive goals?"

Research methodology

In order to answer to the first research question, we propose the next logical step in the evolution of educational paradigms named *Learning by Being* (LBB) when the student not only knows the learning objectives, but also assumes them. Here we should speak about the *ownership of cognitive goals*. There is a series of approaches related to learning by being such as independent research with IF= 0,83, knowledge of success/evaluation criteria and the existence of tendency to reach these criteria with IF=1,13, or revealing similarities and patterns IF=1,32. Since LBB approach integrates several efficient strategies, due to the synergy effect, its impact is much higher than the given numbers. Thus, simultaneous or parallel application of such didactical strategies, based on deep intrinsic motivation, would give strong cumulative effect [6]. 1. The main idea of LBB concept consists of two moments: intrinsic motivation and cognitive effort. In order to achieve the assumption of cognitive goals, the learning objectives must be challenging and exciting for students, according to their current level of knowledge according to "Vygotsky's Zone of Proximal Development". Here a well-known didactical principle of learning with effort will be respected, because only the effort develops, and any ascension requires effort. For a better assimilation of cognitive goals of the lesson, we can group the learning objectives into BSI. So, a set of learning objectives within LBB corresponds with BSI of an IBSE project. In order to obtain a more advanced involvement of the students, we may prepare a series of Guiding Questions such as:

a) What do you think should follow previous subject?
b) What are the aims of today's lesson?
c) What do we already know and would it help us to reach today's goals?
d) What should we do in order to achieve our goals?

As we can see from the structure of these questions, we actually prepare students for inquiry-based learning. Such type of learning will be a successful one if the impulse for research is intrinsic for the student. But appetite comes with eating. In this way, in order to form this intrinsic motivation, it is necessary for students to be familiar with inquiry or IBSE projects. Students' research skills become sustainable if we will start IBSE projects as early as possible, even in kindergarten, or in primary school [10].

In order to answer to the second research question, let's examine the role of the teacher within LBB. As we already stated in this communication, there is no efficient teaching without active involvement of the student, in the same way there is no successful learning without teacher guidance. Thus, the student – teacher interaction acts as a harmonic oscillator, with features determined by both of its constituents. In other words, we have to ensure mutual permanent feedback – according to the theory of Visible Teaching and Learning. This interaction has the concrete form of guidance. Thus, we can talk about guided self-scaffolding (IF=0,78) which is based on three pillars: feedback, students' independent research and previous knowledge of students. Within guided self-scaffolding the teacher will teach the students to ask themselves the following four guiding questions (*Table 1*):

Table 1. *4C questions model*

Did it	**Confirm** what I already knew?
	Complete what I already knew?
	Cancel what I think I knew?
	Challenge me for deeper research?

Thus, we arrived to the scheme through which new knowledge is connected with previous one. Learning with this scheme can be easily performed even in primary classes, when pupils are taught to summarize the text they read. In fact, this process lays the foundations for the formation of critical and analytical thinking, which will facilitate learning through research in middle school and in high school.

Another important goal of the teacher is to permanently increase student's metacognition. Shortly the metacognition assumes that the students:

a) analyze what strategies they will use in order to accomplish the task;
b) argue why they have selected a certain strategy;
c) estimate the possible result;
d) analyze the obtained result;
e) decide if it is necessary to change the strategy for carrying out the task.

Thus, awareness and understanding by students themselves of their way of thinking in the case of learning is more than applying a learning strategy, taken from the teacher. In this way, the metacognition is equivalent to the didactical principle of conscious learning and closely relates to the assumption of learning objectives by the students or "students' internal guidance" [11]. The same thing happens in performance sports, when the athlete not only knows what the coach wants from him, but assumes the coach's tasks as his own goals and has all the physical, technical, tactical and emotional means to achieve his goal, which was originally set by the coach. Moreover, sustainable learning assumes that the student understands his own learning, the way he/she thinks and acts. The teacher's role in building student's metacognition is crucial.

First, teacher himself is a model for metacognitive thinking explaining his thoughts loud.

Second, the teacher provides explicit instruction in metacognitive strategies, explaining how and when students should use each particular strategy.

Third, the teacher should provide metacognitive feedback, helping students to evaluate their own learning strategies and adjust their cognitive processes.

Fourth, the teacher should create opportunities for students to practice and develop their metacognitive skills in various learning contexts. In this way, learning is more than applying a strategy, taken from the teacher.

Fifth, even the differences between conscious learning and metacognition are practically imperceptible, however, we will emphasize that conscious learning focuses on the awareness and conscious use of learning processes, and metacognition focuses on the awareness and control of the cognitive processes themselves.

In this way, the metacognition practically is close to the didactical principle of conscious learning and closely relates to the assumption of learning objectives by the students.

Conclusions

The assumption of cognitive goals in Learning by Being allows us to qualify LBB concept as an *objective-driven pedagogy* or “la pédagogie par objectifs” where the teacher and students have the same goal.

The synergy effect due to the overlapping of several didactical techniques. Within LBB we use in the same time, within the same research project, several techniques, all of them with highest impact factors. It is expected that there will be a synergy effect, but this fact should be demonstrated through pedagogical experiments. Even if the synergy effect would be minor, slightly above the IF of the components, the resulting IF of the LBB would be about IF=1,2 or 3 times higher than in the case of frontal teaching (IF=0,4).

The preconditions for LBB, namely intrinsic motivation and cognitive effort, are developed in the frame of permanent inquiry-based projects which started very early, even from primary school.

The teacher’s role in LBB is to form and enhance students’ metacognition by:

a) Modeling metacognitive behavior;
b) Providing explicit instruction on metacognition;
c) Providing metacognitive feedback;
d) Creating opportunities for students to practice and develop their metacognitive skills in various learning contexts.

References:

1. https://eric.ed.gov/?q=Motivation&ff1=dtySince_2020 [accessed on 09.05.2024].
2. BRAKHAGE H., GRÖSCHNER A., GLÄSER-ZIKUDA M., HAGENAUER G. Fostering Students' Situational Interest in Physics: Results from a Classroom-Based Intervention Study. In: *Research in Science Education,* 2023, 53:993–1008, https://doi.org/10.1007/s11165-023-10120-x13.
3. OON, P., SUBRAMANIAM, R. On the Declining Interest in Physics among Students – From the perspective of teachers. In: *International Journal of Science Education*, 2011, 33(5), 727–746. https://doi.org/10.1080/09500693.2010.500338.
4. POTVIN, P., HASNI, A., SY, O. Using inquiry-based interventions to improve secondary students' interest in science and technology. In: *European Journal of Science and Mathematics Education. 2017, 5*(3), 262-270. https://doi.org/10.30935/scimath/9510.
5. SZYMAŃSKA-MARKOWSKA, B. How does IBSE affect physics teaching?. In: *European Journal of Physics Education*, [S.l.], v. 14, n. 1, p. 23-34, June 2023. ISSN 1309-7202. Available at: https://www.eu-journal.org/index.php/EJPE/article/view/351. [accessed on: 09 May 2024].
6. CALALB, M. The Constructivist Principle of Learning by Being in Physics Teaching. In: *Athens Journal of Education*, 2023, vol. 10, pp. 139-152. ISSN 2241-7958. DOI: https://doi.org/10.30958/aje.10-1-8.
7. DONOGHUE, G.M., HATTIE, J.A.C. *A Meta-Analysis of Ten Learning Techniques. Front. Educ*., 31 March 2021, Sec. Educational Psychology. Volume 6. https://doi.org/10.3389/feduc.2021.581216.
8. HATTIE, J.A.C. Visible learning: a synthesis of over 800 meta-analyses relating to achievement. 1st Edition. Routledge. http://dx.doi.org/10.4324/9780203887332.
9. BAO, L., KOENIG, K. Physics education research for 21st century learning. In: *Discip Interdscip Sci Educ Res* 2019, 1, 2. https://doi.org/10.1186/s43031-019-0007-8.
10. CALALB, M. Correlation between Visible Teaching and Inquiry-Based Learning, Proceedings of the World Conference on Teaching and Education, 18 – 20 October, 2019, Budapest, Hungary, pp. 81-88.
11. http://dx.doi.org/10.33422/worldcte.2019.09.566.
12. KIRSCHNER, P.A., SWELLER, J., CLARK, R.E. Why minimal guidance during instruction does not work: an analysis of the failure of constructivist discovery, problem-based, experiential, and inquiry-based teaching. In: *Educational Psychologist* 2006, 41(2), 75-86. http://dx.doi.org/10.1207/s15326985ep4102_1.