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Review *Habilitation Thesis* - ***Implementation of Inquiry-Based Learning into Chemistry Teaching*** author dr Paweł Bernard

The work of dr Paweł Bernard evokes mixed feelings. On the one hand, I am impressed by the number of publications with Impact Factor, the number of publications indexed in WoS, Scopus, and the number of citations. I am also impressed with the patent he is co-author. It cannot be denied that such achievements do not appear very often in the field of Chemistry Teaching.

On the other hand, the topic chosen by the Doctor as his habilitation thesis topic is a topic that has been known for a very long time. Its official beginnings date back to the 1960s, so it can be considered that it is a frequently exploited topic. Even cursory searches confirm this. If we enter the topic of the Doctor's habilitation thesis in the Google Scholar search engine, we get over 35,000 scientific articles related to this topic. Therefore, the question arises: Has the Doctor found anything new in such a widely researched and long-studied field, did he find new research questions, or indicated new research directions?

As we know, obtaining the degree of associate professor should allow us to indicate new research directions and new ideas for theories. The postdoctoral researcher should show the contribution of new solutions and ideas in a given field. Has this happened as a result of Dr Bernard's work? I think I will answer that later in the review.

In order to find new research directions, ask new questions or draw new conclusions from what has already been researched and thus point out a new path, an in-depth knowledge of the history of the described/researched problem is needed. Unfortunately, however, the work of Dr Bernarda lacks these elements. There are no citations regarding previous Polish research on this topic in the quoted literature. There are also no citations of works by Czech or Slovak authors (the lack of quoting of Prof. Held and Prof. Ganajova is particularly striking). Additionally, the article cites those articles that are consistent with Doctor's erroneous concept that IBL is a new method.

Unfamiliarity with the history of research in a given field and the achievements of researchers in their own country and in the country where the associate professor degree is to be obtained makes it much more difficult to set new trends. However, it is not impossible. Let's take a look at the work from this angle.

General comments

Let's start with the topic of the work: *Inquiry-Based Learning (IBL) in teaching chemistry at various levels of education*. Of course, Dr Bernard, dealing with the didactic of chemistry, studies the application of IBL in chemical education. However, in Habilitation Thesis, I miss the justification and explanation of how the use of IBL in chemical education differs from the use of IBL in teaching other subjects (including science). Without this explanation, a question

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can be asked: *Why is the defense of habilitation not taking place at the pedagogical faculty?* Especially that Dr Bernard himself claims (p. 7 in Habilitation Thesis) that the first part of his work - 6 articles are typically pedagogical research, and in the second part the methodology used is based both on the methodology of natural/chemical research (development of new teaching aids) and humanities / social studies (assessment of the didactic usefulness of the solutions developed).

The Habilitation Thesis also lacks a common research goal, hypotheses or research questions. This gives the impression of individual articles are poorly related to each other. I am aware that habilitation on the basis of the collected articles is governed by different rules than habilitation on the basis of a written book. However, Dr Bernard in Habilitation Thesis did not sufficiently explain the amalgamation of these articles.

In Habilitation Thesis, the term IBL appears, while in the articles the term IBSE is used. The question is whether they are the same terms or are there any differences between them? There is no explanation in the paper as to how they differ and whether they can be used interchangeably. It is good practice in scientific work to give a list of abbreviations and explain how they are used. This explanation is missing from this work.

DETAILED NOTES

Introduction to habilitation thesis

I absolutely cannot agree with Dr Bernard's statement on page 9: *"In general, Western European countries, especially United Kingdom, had more experience in using inquiry-based methods, while Eastern and South European countries were still immersed in behaviourism inherited from socialism with the dominant and leading role of both the school as an institution and the omniscient and lecturing teacher".*

Let me quote a fragment of the Polish monograph entitled ***Co ocalić od zapomnienia w dydaktyce nauk przyrodniczych*** [*What to save from oblivion in the didactics of natural sciences?*] published in Krakow in 2015, a chapter by Anna Galska-Krajewska, Agnieszka Siporska and Wanda Szelągowska, entitled ***"Nowości" dydaktyczne - z wiekowym rodowodem*** [*Didactic "news" - with age-old pedigree*]: *In Poland, even during the partitions, valuable didactic studies appeared (Heilpern, 1912), and after regaining independence, there was intensive development of subject didactics, the latest foreign publications were translated concerning new trends in teaching, their effectiveness was examined in experimental schools, etc. (Czerniewski, 1964; Galska-Krajewska, 1987). Our curricula of that time recommended the method of independent work of students under the guidance of a teacher in teaching science subjects, e.g. chemistry (Harabaszewski, 1932), and biology (Baraniak, 1996; Męczkowska & Rychterówna, 1923).*

The student experiment, recognized as the basis for teaching science subjects, changing the student's attitude from passive to active, was introduced at the end of the 19th century in Anglo-Saxon countries (Harabaszewski, 1932). In Poland, during the captivity period, it

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could only be used in selected schools, but it became obligatory in the interwar period (Galska-Krajewska & others, 2009). The purpose of the student's experimental work is not it was only the acquisition of technical skills, and above all the development of general education intellectual skills, e.g. distinguishing observation from inference, associating, planning, using various ways of reasoning, using an experiment in problem-based teaching (Galska-Krajewska & Pazdro, 1990). Such teaching was promoted in the interwar period by Jan Harabaszewski (Galska-Krajewska & others, 2009; Harabaszewski, 1932; 1936) and Stanisław Pleśniewicz (1927), after the war Józef Soczewka (1975) and others (e.g. Sawicki, 1981). Let us recall that richer proposals were presented by Magdalena Konieczna (Galska-Krajewska & Pazdro, 1990; Konieczna, 1975), describing various types of experiments (introductory, discovering, verifying) applied to solving problems through inductive, reductive and deductive reasoning.

Prof. Held has the same opinion in the publication titled: ***Výskumne ladená koncepcia prírodovedného vzdelávania (IBSE v slovenskom kontexte)***. It is also hard to forget about the pioneering, on a global scale, research by the Soviet scientist Paweł Błonski at the beginning of the 20th century.

It can therefore be concluded that Dr Bernard's statements are untrue.

Part I Research on various aspects of implementation of IBL into school practice

Implementation of IBL into chemistry curriculum in Poland

Articles [P1] and [P2] described in this part refer to the old core curriculum, which is no longer applicable in Poland (page 12). And even though Dr Bernard wrote on page 13: "*Further reforms of Polish education, first changing the structure of the educational system, introducing 8-years-long primary school (K 1-8), and four years-long secondary schools (K9-12) (Polish Core Curriculum, 20 12), and later curriculum updates to the new structure (Polish Core Curriculum, 20 17, 20 18) didn't bring significant changes to recommended teaching methods and conditions of curriculum realization.*" Let me disagree with this thesis. In the new core curriculum, the obligation for students to complete an educational project has been removed. According to the so-called old core curriculum, the student received a grade for the project, which was entered on the final certificate of completion of the gymnasium. Currently, according to the new core curriculum, students do not have to complete projects, so many teachers gave up this cumbersome and time-consuming method of work. This significantly reduced the use of the method of scientific inquiry in Polish education. In the new core curriculum, operational verbs were also changed to lower (according to Bloom's taxonomy). As a result, teachers do not have to require students to think scientifically (e.g. in the old core curriculum there was the phrase "the student explains the difference", in the new core curriculum there is the phrase "student describes the difference"; in the old core

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curriculum: "student defines the concept of ions" in the new core curriculum "the student uses the concept of an ion").

In the chapter entitled: **The wind of change - a study of Polish teachers' beliefs and attitudes toward IBL** articles [P1], [P2], [P3] are discussed. In these articles, the term IBSE and not IBL appears in the titles.

The article [P1] *Introduction of inquiry based science education into polish science curriculum - general findings of teachers' attitude* is a proper introduction to further research. However, Habilitation Thesis lacks information on whether the 33 teachers participating in the FP ESTABLISH project and research were teachers of chemistry or other science subjects. Polish title (*Implementation of teaching by the discovery in the Polish core curriculum in the field of science subjects - a survey of teachers' opinions*) suggests that we are dealing not only with chemistry teachers but all science teachers.

There is also no description of how the surveyed teachers were selected from the group of teachers participating in the project. It also seems to me that the questions asked in the survey may not be clear to teachers. For example, the question "IBSE requires more thinking than traditional methods" - what did the authors mean by traditional methods? Traditional methods include: learning by doing (J. Dewey, late 19th century), problem teaching, etc. These are methods that require thinking. The term "more thinking" is also imprecise. This vague term also appears in the question of time.

The article [P2] entitled *Influence of In-Service Teacher Training on Their Opinions about IBSE* describes the change in teachers' attitudes towards IBSE after the training. It compares the results obtained by teachers before the training (described in [P1]) with the results obtained after the training. The undoubted value of the article is the detailed description of the training included in the appendix of the article. This article is a continuation of the research described in the article [P1]. While it is understandable to publish the preliminary research in the articles and then the results of the overall research, it seems to me that in this case there was no need to include both articles in Habilitation Thesis. The article [P2] contains the content of the article [P1]. In fact, in the article [P1] there is no valuable information that would not be repeated later in the article [P2]. It unnecessarily gives the impression of artificially increasing the number of publications.

In Habilitation Thesis, Dr Bernard writes about IBL, the term IBSE appears in the article.

87 teachers participated in the research, 80 of whom taught chemistry. Perhaps it would be more correct to reject teachers rather than chemists? The author also did not specify how many chemistry teachers were in the randomly selected group of 33.

Development of the teacher education programme

This chapter describes the continuation of research under the FP7 ESTABLISH project and FP7 SAILS. This section focuses on the development of a teacher education program (TEP).

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Creating training programs to increase teachers' competences is an important element in the development of education. Of particular importance is the creation of programs whose effectiveness is verified by scientific research, as we are dealing with in this case. Solid research and in-depth analysis, also statistical, are the strength of this article. However, the training and research program is not just about chemistry teachers. It was attended by 31 teachers of biology, 35 chemistry and 26 physics. The question posed at the beginning of the review returns: ***Whether and how the use of IBL in chemical education differs from the use of IBL in teaching other science subjects***. It can be suspected that there are no particular differences since the training described in the article [P3] on the IBSE method was the same for teachers of biology, chemistry and physics.

There is an inaccuracy in Habilitation Thesis. It is difficult to agree with the statement of the Doctor (p. 16) that *one of the first teacher education programmes for chemistry teachers in Poland focusing on IBL was the one developed within the FP7 ESTABLISH project.* Training in the use of the IBL method, even at Dr Bernard's home University, has been conducted since 2012 (eg at the Faculty of Physics, Astronomy and Applied Computer Science of the Jagiellonian University in Krakow under the program of the Minister of Science and Higher Education - project "Academic Center of Creativity"). Not to mention other trainings.

Articles [P2] and [P3] constitute a logical research sequence: examining teachers' attitudes towards IBSE and preparing appropriate training courses on IBL, and then their evaluation (if we consider IBSE to be the same as IBL).

The chapter **Integration of inquiry-based learning with formative assessment** refers to the article [P4]. The article proposes a new classification of IBSE skills, combining the approaches of Fradd, Lee, Sutman, and Saxton (2015) and Wenning (2007). This is undoubtedly an interesting solution. Two cases of using formative assessment in conjunction with IBSE are described in this article. The use of formative assessment in IBL and/or IBSE is a common procedure, although not very popular in Poland. Google Scholar displays over 80,000 articles for the word "formative assessment in IBSE" and over 2,000 articles for the word "formative assessment in IBL". In this context, this is the correct solution. Formative assessment may or may not be combined with IBL and/or IBSE, however. The Habilitation Thesis lacks a broader explanation of how this article links to the previous ones.

Two teachers were involved in the study, teaching at two different educational levels, with different lengths of service (10 and 20), in classes of different sizes (11 and 5 students). The described observation and thoughts of the surveyed teachers are undoubtedly interesting, but I must agree with the authors' summary of their own research:

Finally, it should be remembered that the teachers participating in the research were extraordinary cases. They were very well educated, experienced and motivated, and still, they faced major problems while completing the task. 'Ordinary' teachers have to deal not only with a challenging combination of inquiry and assessment but also face problems with the

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application of the inquiry process and the introduction of content knowledge. A description of such cases would be an interesting step forward. In this case, it is difficult to say that this research could help ordinary teachers. And that the use of this assessment method was necessary when using the IBL method.

How does training in IBL influence teachers' reasoning skills? [P5]
The article concerns the use of the IBSE method to develop scientific thinking among teachers of science subjects (physics, biology and chemistry). This is another article in which the research group is broader than that declared in the title of Habilitation Thesis.
This is where a serious problem arises.
Article [P5 - Paweł Bernard*, Karol Dudek-Rożycki (2019). ***Influence of training in inquiry-based methods on in-service science teachers' reasoning skills. Chemistry Teacher International,*** 1 (2), 1-12] is based on research conducted in 2014-2015 as part of the SAILS project. There is also an article with the same title in Polish, which is also based on research conducted in 2014-2015 as part of the SAILS project. This is an article: Karol Dudek*, Paweł Bernard, Anna Migdał - Mikuli (2016) ***Wpływ szkolenia z metodologii IBSE na umiejętności rozumowania naukowego u nauczycieli przedmiotów przyrodniczych*** [*Influence of IBSE methodology training on scientific reasoning skills of science teachers*] In book: ***Aktualne problemy dydaktyki przedmiotów przyrodniczych*** [*Current problems in science education*], publisher: Faculty of Chemistry of the Jagiellonian University, Editors: Paweł Bernard, Iwona Maciejowska. As we can see, the co-author prof. Anna Katarzyna Migdał-Mikula and the change of the corresponding author from Karol Dudek to Paweł Bernard. There is also a third article that is very similar to [P5]. This article is: Dudek, K., Bernard, P., & Migdał-Mikuli, A. (2014). ***Reasoning skills of Polish science teachers***. In: ***Science and Technology Education for the 21st Century. Research and Research-Oriented Studies. Proceedings of the 9th IOSTE Symposium for Central and Eastern Europe*** (pp. 78–90). Hradec Králové: Gaudeamus. (This article is not available online.)
I understand that the research within the project can be described several times from different perspectives, but the similarities in both the titles and the content, in this case, are too big. Repeating the same content at length in three articles is incomprehensible.
I do not agree with the statement in the article *Unfortunately, the teachers currently working in Eastern European schools (e.g. in Poland) have had no opportunity to experience inquiry-based learning* ...my experience and the experience of fellow didactic and teachers do not confirm this idea. We were not only taught in this way in primary and secondary school, but also in teacher education, we were taught how to teach in this way. Of course, this information is not included in WoS or Scopus.

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Usage of IBL by chemistry teachers during emergency online teaching caused by COVID-191 pandemic outbreak [P6]

The last article in the first part of pedagogical research on the application of the IBL method in chemistry education has NOTHING to do with IBL or IBSE. These terms do not appear throughout the article. So I don't understand why he was included in Habilitation Thesis. The authors present the experiences of chemistry teachers with the use of online experiments. However, not every use of an experiment in the classroom is tantamount to using the IBSE or IBL methods.

Both in the article and in Habilitation Thesis there are no references to people dealing with the subject of experimentation in Poland (e.g. the group from Toruń dealing with experiments on a microscale, or the group from the University of Poznań dealing with filming chemical experiments), there are also no references to people dealing with experiments on a microscale similar issues in the Czech Republic (eg prof. Bilek and doc. Šmejkal - has been dealing with computer-assisted chemical experiments for a long time and dr. Šulcová, who deals with, inter alia, home experiments, that I will refer only to the employees of Charles University in Prague).

The article is summarised in the authors' words: *We are aware that the presented study raises more questions than it provides answers. As mentioned earlier, it evolved from a monitoring project, and therefore, many of the questions concerned using data loggers during online teaching rather than focusing on more general practices. However, the collected data seem to be quite universal and can be used as an entry point to further, more systematic studies. The teachers participating in this research can be treated as a model group, as they were trained in using ICTs before the pandemic outbreak and in using videoconferencing software for online teaching just at the beginning of the lockdown of schools. This study shows that although they may not have been ready for the situation but maybe were a little bit better prepared than ordinary teachers, they still faced many problems, and their practices did not always meet the students' needs and expectations.*

It seems to me that although the obtained results may constitute a source for further research, the attachment of this article to the Habilitation Thesis is a misunderstanding.

Part II - New didactic tools supporting the implementation of IBL while chemistry classes at various levels of education

Investigation of amphoteric properties of aluminium oxide [P7]

I agree with Dr Bernard that there is a need to develop new IBL-based lesson scenarios. It is also true that the Polish core curriculum for secondary school mentions experience: testing the properties of amphoteric oxides, but alumina is not directly mentioned. In this context, it is an interesting proposition. And the use of a microwave oven to obtain the right grade of alumina is undoubtedly an interesting solution from the chemical point of view. However, from the point of view of implementing IBL in education - it is not so obvious. Although the term

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Inquiry-Based / Discovery Learning appears in the keywords of the article, this term does not appear throughout the article. It is a pity that in Habilitation Thesis, Dr Bernard did not elaborate on the subject of IBL in the context of this article. In its current form, I can only guess that the experiments designed in this way can be used in the IBL method. However, we do not have a ready-made lesson plan for teachers, which is what teachers expect (according to Dr Bernard's research).
I understand the description of the laboratory part rather than the teaching part in this article. However, a broader explanation/description of the research should appear in Habilitation Thesis. Currently, I have a few doubts. First: in the experimental group, the students used the IBSE method, what method was used in the control group? If neither, it is a serious methodological error. Second: the mean difference in the test between the groups is 0.36 (on a seven-point scale), is it a statistically significant difference? Third: how the questionnaire was structured, and how the questions were formulated.
The division of points is also unclear to me. Dr Bernard declares his share of 45%. Considering that very similar studies appear in the doctorate of Mrs Kinga Orwat and the promoter is also prof. Anna Migdał-Mikuli, I have some doubts either about the distribution of points or about the independence of the doctoral student's work.
There is also some ambiguity with regard to Ms Kinga Orwat's doctorate. In the discussed article [P7] dated February 2016, the following numbers of respondents appear in the description of the studied groups: a pilot group of 36 people and 26 in the following year. And in the review of Mrs Kinga Orwat's doctorate of December 20, 2018, the number of respondents - 12 people appears. As the Habilitation Thesis bibliography does not refer to Mrs Kinga Orwat's doctorate, it is difficult for me to verify the situation.

Introduction of the principles of green chemistry based on testing the properties of traditional and UV-cured varnishes [P8]
Introducing the principles of green chemistry to chemistry lessons at all educational levels is an important element of chemical education and, at the same time, a challenge that has been successful this time. Although in the discussed article the term "inquiry-based" appears only 3 times: in the title, in keywords, in the abstract, the described lesson procedure corresponds to the IBSE method. And it can be an interesting example to be used by teachers. It is a pity that the topic is beyond the core curriculum in chemistry for primary and secondary schools.
As the article briefly describes the results obtained, it is a pity that they are not discussed in more detail in Habilitation Thesis.
Here, too, the breakdown of the points is unclear to me. Dr Bernard declares his share of 45% - taking into account that very similar studies appear in the doctoral dissertation of Mrs Kinga Orwat and two more co-authors (one of them performed parallel research at a university in the United States) I have some doubts or about the distribution of points or the independence of the doctoral student's work.

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Similarly, there are discrepancies between the number of respondents in the discussed article (6 groups of Polish secondary school students K9 and K11, n = 72) and dr Kimga Orwat's doctorate (the research group consisted of 24 middle school students and 24 high school students).

Demonstration of basic principles of heterogeneous catalysis [P9]
An interesting idea was to develop an experiment that is suitable for the quantitative analysis of the effect of the number of active centers on the reaction rate, suitable for simultaneous demonstration in a regular classroom or lecture hall. But in the entire article, or even in keywords, the term IBSE and IBL does not appear at least once, and there is no research in the field of chemistry didactics in it. In the summary of the article in Habilitation Thesis, there is only one sentence related to the topic of Habilitation Thesis, It reads: *Such analysis can be performed during the interactive lecture or independently by students after classes in fonn of guided inquiry*. This does not seem to be enough to justify including this article in this Habilitation Thesis.
Considering that the article has 5 authors (of which two professors are in the group "Surface and Materials Chemistry" and one professor comes from the "Heterogeneous Catalysis and Solid State Physicochemistry Group"), I have some doubts about the division of percentages (if 50% of Dr Bernard is other authors 12.5% each?).

Authentic research-based laboratory course concerning modifications of the electronic properties of heterogeneous catalysts [P10]
Although the terms IBSE and/or IBL are missing in the article and keywords, the article fully corresponds to the topic of the Habilitation Thesis. It contains both chemical and educational content. It is a pity that I had to refer to the original article to be fully convinced of this because, in Habilitation Thesis, Dr Bernard treated the teaching content quite briefly.
The article does not define the term 'Authentic Research-Based students' investigations'. As I understand it, this is a term that is opposite to laboratories according to the "cookbook". But isn't the third year of chemistry too late to teach students how to work independently in a laboratory?
This is the most interesting article in Habilitation Thesis from the point of view of didactics of chemistry.

Enhancement of chemical education with 3D printing - construction and usage of low-cost 3D-printed polarimeter [P11]
3D printing technology is increasingly entering education, including teaching chemistry. In this case, using this technology, a polarimeter was designed, printed and tested. There are no terms IBSE and/or IBL in the article and keywords. And the description of the students' research does not show the IBL method. A weak premise for including this article in

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Habilitation Thesis is the following sentence from the article summary: *That fact provides teachers/instructors with a possibility of using those devices not only during basic measurement laboratory exercises but also during independent student inquiry activities.* 3D printing technology is increasingly entering education, including teaching chemistry. In this case, using this technology, a polarimeter was designed, printed and tested. There are no terms IBSE and/or IBL in the article and keywords. And the description of the students' research does not show the IBL method. A weak premise for including this article in Habilitation Thesis is the sentence from the summary of the article: On the other hand, an interesting solution mentioned in Habilitation Thesis is the self-construction of the polarimeter by students/teachers. Despite the fact that they built the polarimeter according to the instructions, i.e. contrary to the assumptions of the IBL.

Using 3D printer pens to draw chemical models [P12]

Modeling the microworld is an important part of chemical education. It allows abstract concepts to be specified. However, when visualizing the microworld, a very important problem is the correctness of the model and whether it does not create erroneous ideas in the minds of students.

In Poland, we have a very long tradition of modeling the microworld. For example, already in the seventies of the twentieth century, Tomasz Szeromski dealt with it, and in his publication ***Modele i modelowanie w nauczaniu chemii*** [***Models and modeling in teaching chemistry***] from 1982, many chemistry teachers were brought up. In the nineties of the twentieth century this topic was dealt with by prof. Janiuk together with his team from the University of Lublin from numerous publications should mention the book: ***Optymalizacja funkcji teorii i modeli teoretycznych w nauczaniu chemii*** [***Optimization of theoretical functions and theoretical models in teaching chemistry***] from 1994. We should also mention the team of prof. Burewicz from the University of Poznań. Or the research of the team from the Pedagogical University of Krakow (to which I belong and which resulted in, among others, the defense of habilitation at the Charles University in Prague in the field of ***Visualization in chemistry and teaching chemistry***). In the Czech Republic, this problem was dealt with by Dr Karel Myśka and Prof. Karel Kolar from the University of Hradec Kralove and prof. Martin Bilek (HK and now UK). In Slovakia, this topic was discussed, among others, by prof. Jarmila Kmetova. It is a pity that neither of these publications is cited in both the original article and the Habilitation Thesis. The fact that Dr Bernard did not know the above-mentioned works causes the models proposed by him to have serious errors. The first of the results from the fact that they are similar to Dreiding's skeleton models, which are used to present the internal structure of models of chemical compounds, to illustrate the angles between bonds in the molecule, and the isomerism of the carbon chain in organic compounds. However, Dreiding's models, and thus the 3D models described by Dr Bernarda, may lead to the formation of misconceptions in the student's mind through, for example, the lack of hydrogen atoms or the lack of an electron

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cloud. In addition, the models described in the article lack a very important utility of Dreiding's models - they do not show the spatial arrangement of atoms caused by rotation around bonds. Therefore, they cannot be used for conformational analysis and other stereochemical studies.

The second serious disadvantage of these models is that in order to build a correct model of a given molecule, the student must first know what type of hybridization each carbon atom has. Therefore, it is not possible to apply these models to primary or secondary school in general classes. On the other hand, if students are already at such an educational level that they know the hybridization of individual carbon atoms in the molecule, they can imagine the model of the molecule and do not need material teaching aids.

The Habilitation Thesis does not explain the need for a 3D pen to create particle models. How does such a model differ from traditional Dreiding models, bowl and stick models, space-filling models, or from models created by students themselves, e.g. from plasticine or chestnuts? Only the novelty effect speaks in favor of the models.

There are no terms IBSE and/or IBL in the article and keywords. The description of the tests performed also does not correspond to the IBL method. In Habilitation Thesis, the author writes: *In all cases, classes had a review character. Students first wrote a molecular and structural formula of a given compound and draw the structure of the molecule on the paper. Next, following the instruction, students built the desired molecule template, and draw a 3D model using 3D pens. The research was based on a semi-structured group interview and the PMI - Pluses-Minuses-Interesting thinking tool.* This article does not describe the use of IBL at all.

Summary of the main scientific achievements

In conclusion, Dr Bernard writes that the most important result of the presented research is the developed program of professional development for chemistry teachers. He also wrote that the program was created for the FP7 ESTABLISH project (2010-2013) and extended under the FP7 SAILS project (2012-2015), and was further used in the FP7 ESTABLISH project (2013-2016). There seems to be an inaccuracy here. This description shows that the Department of Chemistry Teaching at the Jagiellonian University has developed training for teachers of science subjects for the implementation of the FP7 ESTABLISH project (in 2010-2013). And then the effectiveness of this training was tested as described in the accompanying articles. Thus, the result of this research is the modification of a pre-existing teacher training program, not its creation.

The course on the navoica.pl platform, described in the summary, entitled ***Kształtowanie postaw badawczych dzieci i młodzieży*** [***Shaping the Research Attitudes of Children and Adolescents***] is addressed (as its founders write) to parents, student teachers and active teachers who want to start or improve the application of teaching methods based on students' independent inquiry. Therefore, the question arises once again: Does shaping the research

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attitudes of students in chemistry differ from shaping these attitudes in other science subjects? So, what exactly is the Implementation of Inquiry-Based Learning into Chemistry Teaching about? The author has not shown this in Habilitation Thesis.

Another term appears in the Learning Outcomes of this course: Inquiry Based Education (IBE). Is it the same as IBSE or IBL? In conclusion, another new term appears, 'inquiry-based teaching and learning' (IBTL). Failure to explain the relationship with other terms used by the author. In one of his articles, Dr Bernard wrote that teachers have a problem distinguishing IBL from problem learning, teaching by doing … . It seems that not only teachers since the author uses them interchangeably in articles, courses or Habilitation Thesis and does not define their dependencies.

In conclusion, Dr Bernard wrote: *Teachers introducing IBL into school practice expect not only methodological and practical knowledge from trainers, but also teaching materials prepared for the method that can be used directly in the classroom.* I totally agree with that. However, there are no such scenarios in postdoctoral theses, therefore it is difficult to assess their usefulness.

SUMMARY

The presented articles, although interesting individually, do not constitute a coherent message. There is no explanation as to why they were put together in Habilitation Thesis. What was the purpose of this? What was the research hypothesis? And what research question is answered by this collection of articles. The habilitation Thesis lacks the presentation of new ideas and solutions in the field of chemistry didactics. No new research questions or indications of new research directions.

The use of interchangeable nomenclature of the discussed learning method (IBL, IBSE, IBE ...) indicates either the author's unfamiliarity with these terms or the negligence in the development of the Habilitation Thesis.

The Habilitation Thesis lacks an explanation of how the use of IBL in teaching chemistry differs from the use of IBL in teaching other science or even arts and humanities. This means the lack of explaining why the defence of the Habilitation Thesis takes place at the chemical faculty and not at the pedagogical faculty.

Considering the fact that the research described in the articles from the first part: ***Research on various aspects of implementation of IBL into school practice*** they concern teachers of all science subjects, not only chemistry, and the MOOC course is addressed to all teachers, I believe that the title of Habilitation Thesis is inadequate to its content. A better title would be *Implementation of Inquiry-Based Learning into* ***Science*** *Teaching.*

Of the presented twelve articles, four articles [P4], [P6], [P9] and [P12] absolutely do not fit the proposed topic in Habilitation Thesis. And the next two [P7] and [P11] only partially match. The content of the article [P1] is included in [P2]. The article [P5] requires an explanation of the appearance of very similar content in two other articles not mentioned in

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the Habilitation Thesis and an explanation of the change of authors. In articles [P7] and [P8] there is an unclear division of points and data discrepancies with the doctoral dissertation of Mrs Orwat. Taking this into account, it seems appropriate to ask for a declaration in the division of points from other co-authors to each article.

Only four articles [P1], [P2], [P3] and [P10] are consistent with the modified topic proposed by me above. And the article [P8] after clarifying the ambiguities as to the data and points corresponds to the original title of the work.

Taking into account all my comments and reservations, I believe that in its current form, Habilitation Thesis does not meet the required conditions fo ciate professor.

Dr hab. Małgorzata Nodzyńska-Moroń prof. UP