REVIEW

On Dissertation title: **Areas of Difficulty in Chemistry Curriculum from Students' and Teachers' Perspectives. Students' difficulties in learning basic level organic chemistry**

of **Kalin Nikolaev Chakarov**

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To acquire a “Doktor” (PhD) degree in professional field 1.3 Pedagogy of training in... (Methodology of chemistry education)

Scientific supervisor: Assoc. prof. Alexandria Ivanova Genjova, PhD

Reviewer: Assoc. prof. Nadezhda Stefanova Raycheva, PhD

Procedure data

Kalin Chakarov is enrolled in regular doctoral studies with Order RD 20-247/ 28.01. 2019 of the Rector of the SU. He was dismissed with the right of defense from 01.02.2022 by order RD -20-52/ 14.01.2022. of the Rector of the SU. On 30.01.2023 examination of the dissertation work was conducted in the primary unit, from which the protocol was presented. Based on the positive assessment of the primary unit, a public defense procedure was opened and a scientific jury was appointed by Order No. RD-38-87/16.02.2023 of the Rector of SU "St. Kliment Ohridski". The doctoral student has submitted all necessary documents in accordance with Art. 67 (5), items 1-7 of the Regulations on the terms and conditions for acquiring scientific degrees and holding academic positions at SU "St. Kliment Ohridski" - curriculum vitae, diplomas for previous educational degrees - bachelor's and master's, certificate of exam results during training, dissertation work and abstract to it, declaration of originality and credibility (according to Art. 27, par. 2 of the AR of LDASRB), copies of the articles related to the phd thesis and a certificate of compliance with the national minimum requirements for the ESD "doctor" for the relevant scientific field. In addition to the above, a Report on the similarity of the text of the dissertation in a plagiarism prevention system and a protocol for verifying the originality of the dissertation, as well as an opinion from the supervisor, are attached. The conclusion of the check shows that "the discovered similarities in the dissertation work are regulated and do not bear signs of plagiarism."

Finding based on procedural data: All documents required for the procedure are available and no procedural and scientific-ethical violations were found.

Relevance and originality of the research design

The research of Kalin Chakarov is placed in an indisputable way within the research framework of methodology of chemistry education. It refers to one of the central problems of education, related to the selection and structuring of curriculum. This problem is inherently multi-layered and the influences are multi-factorial. They derive, at the highest level, from the paradigm of education embedded in the relevant educational policy and extend to all sides of the educational process. In the research, one specific perspective was chosen, already outlined in the topic, namely through the subjective opinion of the two key participants in the process - teacher and student. In the introduction of the dissertation, the choice of the topic is justified mainly through the prism of the learning outcomes and the students' choices. As arguments, it was noted that the students put chemistry as the second least liked subject and an ever smaller part of them choose it as a profiler, which is also related to the low results of the Bulgarian students in this subject. Based on these data, the topic was selected and the goal and research questions were formulated, which are aimed at finding an answer to the reasons that led to this condition. The formulation of the research topic and its purpose are two-fold, referring to the search for areas of difficulty in the chemistry curriculum and to students' difficulties specifically in learning organic chemistry. This naturally had an impact on the derived research questions, which were differentiated as four main ones, but in fact the first formulated question consisted of three research questions - about the topics that are difficult, about the reasons for the difficulty and about the relationship between the opinions of teachers and students on these questions. The remaining three formulated questions refer to the second research component – the difficulties in studying organic chemistry. Two of them refer to the opinion of students, and the last one is aimed at teachers - it covers their knowledge about the nature of difficulties and their causes on the one hand, and on the other hand the reflection of this knowledge on their pedagogical decisions, defined by the author as "effective methods of teaching'. The two-component nature of the research has also directly affected the stages of the empirical period of the study - the first (April 2018 - March 2019) is dedicated to "difficult topics in the chemistry curriculum", and the second (June 2020 - June 2021) is related to the difficulties in teaching and learning organic chemistry. Research methods are adequate to the purpose and research questions and include: theoretical analysis, survey, semi-structured interview, diagnostic test and statistical methods.

Finding of relevance and originality of the research design: The research is dedicated to a current problem for the theory and practice of chemistry education. It is

unquestionably justified as a practical need and is implemented according to an original methodology relevant to the research purposes.

General characteristics and structural features of the dissertation

The dissertation has a total volume of 167 pages, of which 119 pages are the main text, 29 pages are references and 18 pages are appendices. The structuring is in six chapters, with the introduction and conclusion also designated as chapters - one and six, respectively. In the introduction, the choice of the topic is justified, the goal, research questions, tasks, main methods, periods and scope of the research are formulated, a brief presentation of the substantive highlights in the structure of the dissertation is made, the content of the main concepts is clarified. The second chapter is devoted to a theoretical analysis of the literature on the problem of the sources of difficulty in teaching chemistry and to research related to the differentiation of areas of difficulty from the point of view of teachers and students. This is followed by a specific study of the sources of difficulty in learning organic chemistry in relation to the specifics of the relevant learning content according to secondary school regulations and an analysis of existing research on difficulties in learning organic chemistry. The third chapter, called the methodology of the empirical research, presents the chronology of the research in stages. Research questions were re-formulated for each stage – seven in total for the first stage and four for the second stage. The scope and design of the research instrumentation and technology for analyzing the results are described. The presentation of research objective, questions and objectives in the introduction and then in this third chapter, with unclear coordination, relationship and correspondence between the research questions in these two places in the thesis, causes confusion. This could probably have been avoided if the description of the methodology had been centered in one chapter, and the introduction had been freed from specific methodological formulations. In the next two chapters - fourth and fifth - results and discussion are presented in the first and second stages of the empirical period of the research, respectively. The conclusion is designated as chapter six, in which the research questions are answered. Unfortunately, there is a different numbering of the research questions than in the methodology, for example research questions from the methodology marked 2.1. , 3.1., 3.2., 4., 5.1., 5.2. and 6. are respectively designated here as: 1.4, 1.5., 1.6, 2., 3.1, 3.2. and 4. This creates further confusion and difficulty in following research from conception to outcome. The conclusion also includes limitations of the study, contributions of the study, suggestions for application of the results, and prospects for future research. The text contains 60 tables, of which 7 are summaries related to the theoretical analysis, and the rest are related to the diagnostic

toolkit and empirical data. Despite the relatively large number of tables, they do not create the impression of dominating the text and really help to summarize and visualize the information. The text is also supported by 15 figures, of which 8 are directly related to the presentation of results. The number of applications is six and they contain the complete diagnostic toolkit - questionnaires for teachers and students in the two stages of the research, the diagnostic test and the expert judgement sheet.

Finding on the structuring of the dissertation: In general, the structuring makes a good impression, with an attempt to facilitate orientation in the text.

There are some atypical solutions such as:

- **designating the introduction and conclusion as "chapters";**
- **presentation in the introduction of the aim and research objectives and again their presentation in the methodology;**
- **the contributions are included in the conclusion. It would be better if they present in a more obvious way because they are central to the research.**

There is also some discrepancy in the way of formulation the research questions in the introduction and in the methodology as well as divergence in their numbering in the methodology and in the conclusion.

Characteristics of the conducted research

The research was conducted in the following periods - theoretical-conceptual, empirical - with two stages and concluding-resultative, described as content on page 3 of the dissertation. Theoretical analysis is generally devoted to the sources of difficulty in teaching chemistry and to a survey of research on these problems in the scientific literature.

In presenting the sources of difficulty, Kalin Chakarov mainly groups them into external and internal, from the point of view of the students. The external ones derive from the nature, the specificity of scientific knowledge in chemistry and its corresponding design in curriculum of chemistry. In the dissertation are commented and substantiated features of chemical knowledge according to the model of Johnstone since 1982 and its amendments from 1991 for the three levels of chemical knowledge, referred to by the cited author as a "chemical triplet". These three levels are re-located as a source of difficulty at the highest level as a necessity for multidimensional thinking. The features of chemistry as a science are commented as a source of difficulty by Kalin Chakarov as two separate - "nature of chemistry" and "multidimensional nature of chemistry", which are actually parts of a whole and could have been subsumed under "nature of chemistry". When concretizing this concept, phenomenological characteristics of

chemical knowledge come to the fore, which are commented on consistently and independently in the text, such as: use of modeling and connection with mathematics in the explanatory function of science, presence of a parallel, own symbolic language, application of practical activity in the heuristic function of science. The selection and structuring of curricular knowledge in chemistry is also quite rightly seen as a separate source of difficulty. Here it is striking that mainly Western authors are cited, and this is a major problem in the methodology of teaching chemistry and has its own national specificity, based on traditions in education, which is greatly underestimated by the phd student in this part of the dissertation. Internal sources refer to the specifics of cognitive processes – cognitive abilities considered in dynamics, a model for the transition of information from the outside (through perception) to the inside (by organizing with the participation of memory resources in relation to previous available knowledge), the emergence of alternative concepts. Apart from them, other psychological phenomena that influence the perception of difficulty in learning, such as: attitudes, interests, motivation and self-efficacy, are considered as a factor.

An extensive analysis of research on areas of difficulty in chemistry from the perspective of teachers and students conducted in different countries - Nigeria, Sweden, Brazil, India, Czech Republic, South Africa - is carried out. The results of these studies are summarized in table 2.1 on page 34 of the thesis. It was concluded that the difficulties are related to the "abstract nature of the learning content, the need for mathematical knowledge and insufficient laboratory classes".

The exhibition continues with an analysis of the difficulties in organic chemistry training, where the situational specificity of the research is clearly outlined, related to the legally regulated requirements regarding the results of organic chemistry training at the basic level. The description is sufficiently complete and from different angles, including a chronological view, showing the knowledge and skills that were formed in a previous period (including from the 5th and 6th grades) and are a prerequisite for the students' success. A survey of research on difficulties in learning organic chemistry was conducted, noting that most research was done with undergraduates. The main topics that are indicated as difficult are summarized in the table. 2.7 on page 43 of the dissertation. Areas of difficulty in the study of organic chemistry and their causes are also presented as conclusions on page 50 of the dissertation. All of them are related to the diversity of organic compounds, tied to different ways of symbolic representation and the abstract nature of considering reaction mechanisms.

The theoretical-conceptual period is described in sufficient depth, logically and with a demonstration of knowledge of a significant part of the research experience on the problem.

The empirical period is presented in two stages. The samples are described in detail and are sufficiently representative - in the first stage, 321 students and 20 teachers from different types of schools were included, and in the second - 457 students, of which 379 of which in the main study participate. They are from different types of schools and from different settlements, incl. small towns and villages. Fifty-six (56) teachers with different experience and different level of postgraduate training are included also.

The results related to the differentiation of difficult topics in chemistry, from the students' point of view, are presented in the table. 4.5 and in fig. 4.1 on page 77. The conclusion made by Kalin Chakarov is in sync with what has been described as experience in other studies - topics that "mainly contain abstract concepts, require mathematical skills or have specific logic, terminology and symbolism" are difficult. Topics, identified as interesting are presented in table. 4.7 and in fig. 4.2 on pp. 79 -80. The results are also similar to those obtained in other countries. It was also found that there was no correlation between perceived difficulty and interest in the topics (Fig. 4.3, p. 81). A discrepancy was also found between the topics that the teachers think are interesting for the students and those that the students themselves indicate (table 4.16, page 86), as well as in the understanding of the significant learning results (table 4.17, page 87).

From the second stage of the research, the areas of difficulty in studying organic chemistry, according to a diagnostic test conducted with the students, are presented in the table. 5.6 on page 97, and the subjective difficulty is presented in table. 5.10 on page 101. The teachers' opinion on areas of difficulty are presented in the table. 5 on page 108 and the PhD student notes that they rate the difficulty of basic organic chemistry much higher than the students. The reasons for the difficulties, according to the teachers, are summarized in similar planes as the reasons for difficulties in chemistry education brought out in the theoretical analysis.

The empirical research was carried out with a representative sample of teachers and students and with a carefully structured diagnostic toolkit, including various methods, which allowed obtaining a large amount of data. This, in turn, has enabled a high level of objectivity of the obtained results and their interpretation.

Contributions of the study

The dissertation summarizes three contributions that directly derive from the purpose and research questions and emphasize that for the first time in our country such a study is being done, which is directed to the interesting topics in chemistry education, according to the students, to the difficulties in education in chemistry and in particular in organic chemistry "at the basic level" through the opinions of teachers and students.

The formulated contributions are objective and reflect what was actually achieved in Kalin Chakarov's research.

Analysis of the articles and the abstract

The research was popularized through four articles, of which one was independent and three were co-authored, as well as through two participations in scientific forums, respectively: XIX National Conference on Chemistry for Students and Doctoral students of the Faculty of Chemistry and Pharmacy of SU "St. Kliment Ohridski", held in 2021 and a National Conference with international participation "Natural Sciences 2021" at Konstantin Preslavsky University of Shumen. One of the articles is in a journal Pedagogy, which is referred in Web of Science and in other field-specific databases (ERIH PLUS, CEEOL, EBSCOhost, Google Scholar), and the others are in a journal Natural Science and Advanced Technology Education, which is also referred in science-specific databases (Chemical Abstracts, Google Scholar, EBSCOhost, CEEOL, Science Index).

The Abstract has a total volume of 42 pages, of which 35 pages are the main text. It briefly presents the main points of each of the chapters in the dissertation. Structuring repeats this in the dissertation.

Questions and recommendations

I have the following question for the PhD student:

How did the theoretical analysis affect the content of the diagnostic toolkit that was applied in the empirical stage of the study?

Conclusion

The dissertation research conducted and presented by Kalin Chakarov is comprehensive and well-grounded with significant results for the development of Methodology of Chemistry education in a theoretical and practical aspect, with a subsequent significant impact on the chemistry teaching process not only in secondary schools, but also in higher schools in the

country. As a concept and methodology, it has wide possibilities for transfer and a good starting point for other studies devoted to curriculum in the country as a whole.

Based on all findings of a procedural and structural-content nature presented in this review, I strongly recommend to the members of the scientific jury to award Kalin Nikolaev Chakarov educational and scientific degree "Doctor" (phD) in professional field 1.3 Pedagogy of teaching in... (Methodology of chemistry education).

20.04.2023

Reviewer: ……

(Assoc. prof. Nadezhda Raycheva, PhD)