REVIEW

on the dissertation work entitled

"Comparative analysis of educational content in atomic physics in different countries"

with author **Konstantin Plamenov Ilchev**,

presented for the acquisition of the degree of "Doctor" in the professional direction 1.3 Pedagogy of education in ... (physics)

by **Prof. Victor Ivanov**

1. Relevance of the problem and motivation for the presented research

The recently published results of the international PISA study have met a significant public response, since they show serious systemic problems in the teaching of natural sciences in Bulgaria, and physics in particular. The results of Bulgarian students affect not only the prestige of our educational system. They are an alarming indicator of the lower competitiveness of graduates of Bulgarian schools on the international labor market in the field of new technologies and could lead to an outflow of investments in a number of high-tech industries. Therefore, it is of fundamental importance to identify the difficulties in mastering the learning content of physics in secondary school and to propose innovative methods for effective teaching and for objective assessment of student results.

The present dissertation addresses an important aspect of this problem by means of a comparative analysis of the teaching content of atomic physics between different countries, a number of which have significantly better performances in international educational assessments. As a specific field of knowledge, atomic physics has been chosen particularly well, because important concepts and ideas from modern physics are introduced here, which are directly related to the understanding of modern technologies.

Through a thorough statistical analysis of PISA and TIMSS results and after a systematic study of specialized literature over the last twenty years, the candidate reaches important conclusions and specific recommendations regarding the optimization of the teaching content of atomic physics in secondary school. New interactive methods for teaching have been tested in school, and the progress of students has been examined using modern quantitative methods.

2. Structure of the dissertation

The dissertation is written on 182 pages and contains:introduction;

• three chapters presenting original results of the author's research;

• conclusion;

• a brief summary of the main scientific contributions of the dissertation;

• a list of the author's publications on the subject of the dissertation;

• list of cited literature – a total of 129 titles;

• an appendix presenting tests developed and approved by the author to assess students' knowledge.

The abstract is presented in both Bulgarian and English, and covers to a large extent the content and main conclusions of the dissertation.

It makes a good impression that the main content of the dissertation is dominated by a presentation of the author's original results. The introduction to the dissertation, as well as the introductions to the individual chapters, is atypically small in volume compared to other doctoral dissertations I have reviewed. However, the dissertation does not suffer from this; on the contrary, the content of the introductory parts is concise, with many references and sufficiently convincing from the point of view of the motivation for the research presented.

3. Content analysis of the dissertation and main scientific contributions of the candidate

Chapter 1 is devoted to a thorough statistical analysis of the results of the TIMSS and PISA studies on the one hand and the atomic physics curriculum in different countries on the other hand. The chapter begins with a short but meaningful presentation of the methods of comparative education, justifying their use in the research. In order to apply statistical methods in the comparison of the educational content in a large number of countries, the author very successfully identified 19 content indicators from the curriculum, corresponding to topics in atomic and nuclear physics in the 10th grade of secondary school in Bulgaria. Each of these indicators is used as a key expression whose presence or absence can be traced in the curricula of other countries. In addition, the author introduces four additional indicators that are not represented in the atomic physics curriculum in Bulgaria.

The comparative analysis presented in Chapter 1 leads to several important conclusions with a high level of statistical significance. First, there is an inverse correlation between the amount of material studied and the average score of TIMSS advanced ($p = 0.04$). The author explains the established relationship with the action of a number of factors. In addition to the purely psychological stress associated with information overload, the large volume of material does not give teachers the opportunity to prepare diverse and meaningful activities for consolidation and practical application of new knowledge. The second conclusion ($p = 0.01$) shows that there is a positive correlation with the diversification of teaching methods in class.

The author also gives valuable guidelines for restructuring the secondary school curriculum in physics and astronomy, with the aim of more effective learning of the learning material:

• reduction of the number of mandatory topics from the section and transfer of emphasis to basic topics and concepts from physics;

• freeing up more time for exercise;

• greater choice regarding topics depending on the profiling of a specific school or class;

Although my scientific profile is outside the pedagogy of teaching physics, my personal experience of preparing exam materials for State exams in physics and astronomy fully supports the author's conclusions. Dozens of inconsistencies in the current curriculum can be pointed out, which prevent a clearer and logically consistent presentation of physics at school. For example, in the 10th grade, the concept of fundamental interactions and particles mediating the interaction is introduced, without the students even knowing the law of the most universal interaction in nature – gravity. The concept of a "de Broglie wave" is introduced and students are expected to calculate its wavelength without ever being familiar with the far more fundamental concept of momentum. It seems reasonable, in accordance with the conclusions of the dissertation, that the study of such concepts should be reduced, and the freed resource of hours should be directed to a deeper study of the foundations of physics.

After the author substantiates the need for more diverse teaching methods, in chapter 2 of the dissertation a systematic review of specialized literature from the last 20 years is proposed, which deals with aspects of teaching atomic physics in secondary school. This research provides the necessary basis to test different methods in a real school environment, as described in the following parts of the thesis. Candidate's original contribution to this chapter is in the developed methodology for thematic дхвсхе search of publications and the methods for summarizing and analyzing the data. He chooses the so-called "key features" to search in the bibliographic databases. The key features are 19 specific teaching methods such as discussion, presentation, observation, group work, etc. The found literature sources are organized in a tabular form and sorted by the subject they relate to – atomic physics, nuclear physics, particle physics, etc. The key features present in each article are marked in the corresponding rows of the table. This organization of the data allows the author to easily identify the most preferred teaching methods according to its frequency of occurrence in the database.

I believe that the analysis proposed in this chapter is also of significant practical importance for both high school teachers and university professors in the introductory courses of physics. For example, the traditional approach in Bulgaria, both in textbooks and in the teaching of physics and astronomy in class, is with an emphasis on identifying formulas describing the phenomenon and quantitative analysis of the results of calculations. Indeed, from the point of view of a professional physicist, such an activity is useful in that it gives an idea of the order of magnitude of the physical quantities. On the other hand, however, it seems that such an approach is quite boring for most of the students and the results of the author's research convincingly show this fact. According to the data presented, quantitative analysis is not among the most preferred teaching methods and is therefore relatively rarely employed. Far more preferred according to the research are, for example, the interpretation of data and establishing relationships between the studied material and everyday life. In frequency of use, these methods even overtake presentation activities and the computer assisted teaching.

At the beginning of chapter 3, the author formulates seven specific research questions related to the impact of innovative methods of teaching atomic physics on student achievement, the persistence of their knowledge, the acquisition of traditionally difficult concepts, etc. For the purpose of the study, the author compiled short input-output tests that were given to the students at the beginning and at the end of each of a series of four lessons in order to track the progress of the students within each individual lesson. Next, students are given four versions of an 18-question summative test to test the durability of their knowledge. Variety of methods have been used by the author in the class, encouraging the personal initiative of students – use of simulation computer programs, "students explain to adults", theatrical visualization, working and expert groups, etc. Based on the results of the pre-test and post-test, the author calculates the degree of knowledge upgrading - both on individual tasks and on topics as a whole, by means of the Hake's coefficient. In general, the methods used by the author lead to a high degree of knowledge upgrading with a Hake coefficient above 0.5. One notable exception is the topic of the hydrogen atom and atomic spectra, where the average g value is only 0.28. In my opinion, this low level of upgrading should not be attributed so much to the teaching method – an expert group approach, but to the conceptual difficulty of the subject as a whole. It also provides valuable indications that a broader range of methods, including analysis of quantitative examples, is needed in teaching this topic.

The research described in the dissertation is based on eight out-of-print publications, in four of which the candidate is the lead author and in three others – with a substantial contribution. Two of the publications are in the peer-reviewed and indexed scientific journal Bulgarian Chemical Communications, which falls in the Q4 quartile. The remaining publications are papers published in full text in conference proceedings.

The research results were also presented at eight conferences, in five of which the candidate was the lead author and presented the report.

This high publication and communication proves the candidate's leading role in planning and conducting research. Therefore, I cconvincingly exclude the possibility of any form of plagiarism in the dissertation submitted for review.

4. Notes and recommendations

I have no fundamental objections to the scientific content of the dissertation. I would advise the author to use, where possible, equivalent Bulgarian terms instead of English loanwords.

As recommendations for future work, I would advise the candidate to extend his research to other sections of the secondary school Physics and Astronomy curriculum. It would be very valuable for upcoming revisions of the curriculum to follow how basic concepts from mechanics, electricity and optics are introduced into the programs of other countries. In particular, I would point out concepts such as "momentum", "centripetal acceleration and centripetal forces", "principle of superposition", "polarization of light", etc., which are currently not present in the national curriculum. I would also encourage the candidate to promote his research to a larger community of physics teachers, as well as relevant education policy-making bodies.

5. Questions for the candidate

1) In the Physics and Astronomy curriculum for the 10th grade, percentage ratios are defined between the lessons for new knowledge (up to 60%), exercises (at least 16%), discussion and summary (up to 7%), practical activities (at least 11 %) and control and evaluation (up to 6%). These parameters largely determine the structure of the textbooks and the way teachers distribute the learning material throughout the year.

• Are similar norms defined in the curricula of other countries?

• Based on the candidate's research, what are in his opinion the optimal values of these ratios?

2) Again, in the 10th grade curriculum, recommended topics for laboratory exercises are given, two of which relate to atomic and nuclear physics – observing and studying spectra, and recording ionizing radiation.

• Does the candidate think it is possible to apply the teaching methods he/she uses to the laboratory lessons?

• Can we apply pre-test/post-test analysis in laboratory lessons?

6. Conclusions

The candidate has presented an impressive volume of research and a deep analysis of the results. Several conclusions important for pedagogical practice are formulated in the dissertation. The research has been presented in a number of publications and reported numerous times at conferences, in most cases the candidate being the lead author. Therefore, I strongly support the awarding of the educational and scientific degree "Doctor" to Konstantin Angelov in PN 1.3 Pedagogy of teaching in ... (physics).

Sofia, 12th January 2024 **Reviewer:**

/prof. D.Sc. Victor Ivanov/