REVIEW

of a PhD thesis

for awarding an educational and scientific degree "doctor" in a professional field: 1.3 Teaching methodology of ... (Doctoral program “Teaching Methodology of Physics“), according to the procedure in the Faculty of Physics, of Sofia University "St. Kliment Ohridski"

The review was prepared by: Assoc. Prof. Ginka Kalcheva Exner, PhD, Plovdiv University "Paisi Hilendarski", Plovdiv, as a member of the scientific jury according to Order No. РД 38-311 / 03.07.2023 of the Rector of Sofia University.

PhD topic: **CREATING AND USING INFORMATION SYSTEMS FOR TEAM PROBLEM SOLVING IN PHYSICS EDUCATION**

Author: **FABIEN TEOFANIS KUNIS**

I. General description of the presented materials

1. Description of the submitted documents

The candidate Fabien Teofanis Kunis has submitted a Dissertation and an Abstract (in Bulgarian and English), as well as the mandatory tables, required for Faculty of Physics according to the Regulations on the terms and conditions for awarding scientific degrees and holding academic positions at Sofia university "St. . Kliment Ohridski". A total of 18 other documents are presented (besides the Dissertation and the Abstract):

- CV (including a list of 7 scientific publications, 18 participations in conferences)
- Order No. РД 20-77 /17.01.2020 for enrollment in the PhD program
- Order No. РД 20-489 /22.02.2023 for the end the PhD program with defense right
- Application for admission to preliminary defense
- Declaration of authorship of the dissertation
- Protocol for checking the originality of the dissertation work
- Opinion of the scientific supervisor Assoc. Prof. Maya Gaidarova, PhD in relation to the procedure for preventing from plagiarism in the dissertation
- Certificate from the Dean of the Faculty of Physics Prof. Dr.Ph.S. G. Rainovski for enrollment, end, and passed exams by the doctoral student;
- List of publications;
- full texts of all 7 publications;
- Book of abstracts from the Ninth International Conference “Modern Trends in Science” FMNS-202, 15 - 19.09.2021, Blagoevgrad, Bulgaria;

- Author reference for the dissertation scientific and practical contribution.

The documents presented by the candidate meet the requirements of the Law on the development of the Academic staff in the Republic of Bulgaria, the Regulations for the implementation of the Law on the development of the academic staff in the Republic of Bulgaria and the Regulations for the terms and conditions for awarding scientific degrees and occupying academic positions at SU "St. Kliment Ohridski".

2. Information about the candidate

Fabien Theofanis Kunis was born in 1986. In 2012, he graduated as "Bachelor" in Engineering Physics, simultaneously obtaining a teacher's qualification. Mr. Kunis' thesis was titled "Computer simulations of nonlinear processes, solitons and chaos". It clearly shows the applicant's interest in working with the advanced information technologies. He continued his studies, and in 2014 he received a Master's degree in Microelectronics and Information Technologies. This deepens his knowledge in the area, corresponding to the topic of his dissertation.

Mr. Kunis has also an extensive professional experience, both in the field of information technologies and as a teacher, judging from his CV. The autobiographical details reveal Mr. Kunis continuous striving to improve his qualifications, participating in 17 different qualifications and courses. Thus, the attempt to "look at" the information technologies from different points of view becomes a guarantee for a successive scientific development of the dissertation.

An additional prerequisite for maintaining the scientific level and in-depth study of the problems and achievements in the field of Mr. Kunis's dissertation are the linguistic competences in English, as well as the ability to use German and Russian languages.

3. General characteristic of the scientific achievments oft he candidate

The PhD topic "**Creating and using information systems for team problem solving in physics education**" shows originality and innovation. It has both purely scientific as well as practical contributions. The investigations give one aspect of the practical solution to the problem of creating modern classroom that can function successfully even in extreme conditions (such as the situation of isolation that occurred during the COVID-19 pandemic).

The effectiveness of teaching and the development of 21st century key competences, as defined and within the framework of the European Union are a function of different elements of the classroom. It is no coincidence that, in the new conditions for work and realization in society, the collaborative problem solving is one of the new key competences chosen in 2015 by the Organization for Economic Cooperation and Development (OECD). It is related to the simultaneous improvement of cognitive and social skills. It contributes to building responsibility, self-reporting, social interaction, and leads to a better understanding of problems. Working in a team, due to the demand to make a collective decision, also teaches the ability to seek compromises and to overcome conflict situations (i.e. it also builds adaptability, leadership, and communication).

Therefore, the creation and implementation in practice of specific educational strategies, methods and techniques for successfully building this key competence is an actual issue and shows the relevance of the chosen PhD topic.

In the introductory part entitled "**Introduction and actuality of the problem**" the goal, tasks, object, subject, scope, methods, and hypothesis of the scientific research are defined.

The ambitious goal, set by the author, is to develop a concept, tools, and models for the formation of teamwork skills in the teaching of physics and astronomy in junior high school and high school and for the formation of the key competence collaborative problem solving in a learning environment (face-to-face or remote). A series of correctly formulated tasks have been drawn up, which indeed lead to the achievement of the set goal.

The research object is students from general education system in junior high school and high school stage of education. The subject of the study is the ability to solve physical tasks as a team. The scope of the study is 2020-2022, coinciding with the term of the doctoral studies. The hypothesis of the research is that with an appropriately selected methodology, it is possible to improve students' skills for collaborative problem solving.

The main part of the dissertation is developed in three consecutive chapters. In **chapter one: Team problem solving**, an overview and analysis of the development of the idea of team (group, cooperative) activity is made, but in the context of the need for new training paradigms of the 21st century, related to a change in the profile of jobs requiring non-routine, analytical, entrepreneurial and technical skills. In these new paradigms, the ability to solve problems, especially in a team, information and communication technology (ICT) skills and creativity come to the fore.

In this context, the ideas of active forms of learning through interactive classes, including critical thinking tasks in processing, analyzing, interpreting information from different sources and generating new (digital) information, looking for solutions, new concepts and generating of new ideas are discussed. Good global practices (Australia, Singapore, USA, etc.) are also sought and the European learning framework had been discussed. The latter is particularly valuable, as it provides guidance on how to assess and recognize skills and competencies, which is one of the most difficult tasks in building soft skills, such as teamwork.

Definitions of teamwork and the ability to solve tasks as a team are given, which also serve as the basis of the proposed methodology further on. Well explain is also the fact that the measurement of this competence cannot be done directly, but by identifying the measurable consequences and effects of its presence. Different evaluation approaches are discussed: by defining sub-competences/sub-processes (steps and behaviors in the decision process) or by comparing individual and team solutions.

The idea of a computer-based problem-solving system (whose concept and framework were first realized in 1999) is also presented. It has also been argued that the computer environment is more controllable because each step in the decision process is recorded. The advantage of collecting

the larger amount of information, in turn, makes it possible to more easily and correctly determine the level of problem-solving skills and the presence of deficits.

Solving time, numbers of steps, number of redundant actions or repeated errors, are indicated as appropriate quantitative evaluation criteria. As an additional advantage of ICT environments, the possibility of interactivity, through the use of simulations, is stated. In them, it is possible to generate different states of the system in order to study its behavior. Thus, the student researches, analyzes and builds his own hypotheses and models for the system, which, supplemented with the steps to reach them, give a sufficiently accurate assessment of the process of building competences for solving tasks.

In this chapter, an analysis of the deficits in the performance of Bulgarian students in the PISA studies is also made, which clearly shows the need to build the competence "collaborative problem solving", which underline the actuality of the PhD topic.

The **second chapter** "**The team problem solving information system**" begins with a general description of the positive influence of ICT in modern education, as a source of resources (e-books, online courses, educational websites, cloud technologies for storage and exchange of resources), new possibilities for teaching (synchronous or asynchronous), remote teamwork (via e-mails, video conferencing, and social media), personalization of learning by applying active approaches (project- and problem-based learning), as well as timely (real-time even) feedback.

Attention is also paid to the role of computer simulations, as attractive, due to their dynamics, interactivity (allow changing various parameters) and the opportunity to experience the training. In addition, simulations allow the creation of models of complex-to-explain scientific concepts or the realistic recreation of real-life situations, giving a good link between theoretical knowledge and practice.

The second subsection of this chapter represents part of the actual creative part of the dissertation. The Lotka-Valera model (*Predator-Prey Model*) is successfully simulated by: 1) the fourth-order Runge-Kutta algorithm and b) by a 100x100 cellular automaton (with a finite number of possible states for each cell), where clear rules for interaction between a certain number of neighboring cells are introduced. The implementation is made in the Java language. The simulations demonstrate the number of predators and the number of prey over time, as well as the relationship between the number of predators and prey.

The third subsection of this chapter is a continuation of the candidate's personal developments and describes the general design of the information system created within the framework of the dissertation, the advantages of which are:

1) works both in the training mode and in the evaluation mode of the "problem solving" and "collaborative problem solving" competences;
2) it can be applied to a wide range of sciences, not just physics and astronomy, which is the specific goal here;
3) works online and offline;

4) can be adapted and customized during the execution of tasks;

5) records the user's activity during operation.

During the system design, special attention has been paid to the comfort of the user, the reliability of the system, its and the tests' validity, usefulness and safety.

The coding of problem-solving skills in it, although it follows the methodology developed for the PISA tests, is also done to develope and not only to assess the competencies for individual and team solving problems. Complex cognitive tasks based on prior general and specialized knowledge and skills are included. The tasks are intended to train skills for: research, understanding, presentation, formulation, planning, implementation, monitoring of the solution and feedback (for possible-solution improvement). To illustrate the capabilities of the "problem solving" competence system, two sample tasks are given in the dissertation: 1) to study the fall of an apple on different planets of the solar system; 2) to study the harmonic oscillation of a mathematical pendulum.

Coding problem-solving skills in a team is one of the achievements of the dissertation. It gives the opportunity to work with both a real and a virtual team. Simulating a team that gives advices and opinion on how to develop the solution process is an innovation that deserves admiration. Another interesting point is that the execution of the tasks does not require prior knowledge of exact physical dependencies, but rather familiarization with the simulations. By suitably varying the parameters of the simulated process, the correct answer can be achieved. Two particular examples of realized tasks are given: 1) mathematical pendulum; 2) connecting resistors in an electrical circuit.

Special attention is paid to team “debugging“, an innovation with invaluable practical application. During learning practice, team members are encouraged to use team tools (shared documents, project management software, performance control systems, etc.) that find application in the real work environment.

In the **third chapter "Research part**" the study of the created system in real practive is described in order to verify the scientific hypothesis of the curent research. The study has been conducted at 125. SU "Boyan Penev", Sofia. The didactic experimental method is used, in which control and research groups participated. There are a total of 132 participants in the age group from seventh to tenth grade. Participants have been randomly assigned. 12 sub-competencies have been tested, as in PISA tests from 2015. Before the start of the experiment, the entry level of the tested competence of each of the students has been established with the help of a test. The evaluation of the work of the participants in the test group is done on the basis of the answers selected during the conversation with the computer agents (virtual team). At the sixth month, both groups has been re-tested similarly to the inital testinig.

On this basis, it is concluded that there is a statistically significant difference, indicating that the mean scores of the experimental group were significantly higher than those of the control group for all sub-competencies. The results of statistical processing of the data by gender (boys / boys) show a better performance of girls, as after training, the difference decreases.

Based on the research, the hypothesis that working with the developed information system improves the skills for: 1) solving tasks, 2) for team solving tasks and 3) for working in a team, is confirmed.

The concluding part of the dissertation contains the conclusions and perspectives for further of developments. This part summarizes that the tasks of the dissertation have been fulfilled, the goal has been achieved and the scientific hypothesis has been proven. In addition, the theoretical and practical contributions of the dissertation are named (*they will be described in the next point of the review*).

The dissertation is structured according to the instructions of the SU, laid down in the Regulations for the terms and conditions for acquiring scientific degrees and holding academic positions at the SU "St. Kliment Ohridski" (art.66. para.2). It consists of: Introductory part (Introduction; Research goals and tasks; Object, subject and scope of the research; Hypothesis and research methods), Main part (within three chapters), Conclusions, Contributions, List of publications, Bibliography, and 5 Appendices.

The volume of work is 192 pages. 197 literature sources are cited, mainly in English and Bulgarian languages, and a significant part of them are from the last 15 years. The sources are books, scientific publications, official strategies and documents from different countries, statistical data from organizations investigating the competence level of students of the studied age group. The dissertation contains 10 tables and 45 figures. The main results of the dissertation have been published in 7 author publications (one still under review) and reported in 18 reports at international and national conferences.

The scientific publications, based on the dissertation, cover the minimum national requirements (according to Art. 2b, paras. 2 and 3 of the Law on the development of the academic staff in the Republic of Bulgaria) in the professional field 1.3 Teaching methodology of ... (PhD program: Teaching methodology of physics).

According to the legal procedure checks (through the submissions by the candidate: declaration of authorship of the dissertation; protocol for verifying the originality of the dissertation work; opinion of the scientific supervisor Assoc. Prof. Maya Gaidarova, PhD, in connection with the procedure for preventing from plagiarism) in the Dissertation and the Author's Abstract no proven plagiarism has been detected.

4. Analisys of the content of the scientfic and applied research achievements of the candidate, as given in the materials for participation in the competition

The applicant's achievements can be formulated as:

1. Scientific

- A thorough and deep analysis of the "collaborative problem solving" competence is made;

- Based on this analysis, a model has been created for the formation and measurable criteria (skills) for evaluating competence, and the model includes: 1) problem-solving skills, 2) teamwork and 3) collaborative problem-solving ;
- Information system has been created based on the teamwork model for solving problems in physics and astronomy. An innovation in this system is the virual team, which allows the system to be used even in conditions of isolation;
- A toolkit has been developed for testing and implementing the information system in a real school environment;

2. Scientific-applied

- The developed information system has the potential to work with a wide range of scientific fields (outside of physics and astronomy), as well as in the field of interdisciplinary problems;
- The information system allows upgrading with artificial intelligence to improve work efficiency (as the author shared);
- The developed toolkit can be applied in the pilot model introduction in all schools, as it has been tested and shows positive results for both compulsory and optional forms of education.

5. Critical remarks and recommendations

I have no critical remarks on the scientific part of the dissertation.

In view of the candidate's future work, I would mention some technical omissions: 1) in some places the used abbreviations and acronyms are not introduced when they first appear in the text; the inscriptions on some figures are too small and illegible; some figures should actually be tables; usually the description of the tables is before, not after them; in the table of contents, the chapters are numbered and contain sub-points that are missing in the main text; literature citation is good to include *ISBN* or *doi* (when available).

6. Personal impressions about the candidate‘s

I have known Fabien Kunis from his participation in the National Conferences on Physics Education, both as an author of scientific investigations and as a leader of students, participating in the youth session of the conference. His contributions show a constant drive to search for innovative and modern teaching methods (for example, the use of free software products, available simulations and the development of proprietary software), fully in synchron with the urgent need to design a modern classroom. Mr. Kunis has a good and understandable style of presenting his developments. In his attitude towards the students, dedication is visible, thanks to which the students also achieve excellent results.

7. Conclusion

After having familiarized myself with the Dissertation, the Abstract and the other materials presented to me, and based on the analysis of their significance and the scientific and applied contributions contained in them, I confirm that the scientific achievements meet the requirements of of the Law on the development of the academic staff in the Republic of Bulgaria and the Regulations for its application and the relevant Regulations of the SU "St. Kliment Ohridski" for awarding the educational and scientific degree "doctor". In particular, the candidate Fabien Teofanis Kunis meets the minimum national requirements in the respective professional field and no plagiarism has been found in the Dissertation, Abstract and scientific works, submitted for the competition.

I give my **positive** assessment of the dissertation.

II. Final conclusion

Based on the above, I recommend the scientific jury to award the educational and scientific degree "doctor" in Professional field 1.3. Pedagogy of teaching in ... (Methodology of teaching physics) of **Fabien Theofanis Kunis**.

14.09.2023 г. Reviewer: .....

Assoc.prof. Ginka Exner, PhD

Note: *When a discrepance between the Bulgarian and English texts is detected, the Bulgarian version is to be considered.*