REVIEW

of dissertation
for acquiring the educational and scientific degree "Doctor"
in the professional field of Pedagogy of Education in...,
procedure at the Faculty of Physics (FF)
at Sofia University "St. Kliment Ohridski' (SU)

The review was prepared by: Prof. Dr. Todorka Zhekova Stefanova from University of Ruse, in her capacity as a member of the scientific jury
according to Order No. RD 38-311/03.07.2023 of the Rector of Sofia University.

Topic of the dissertation: "Development and usage of information systems for team problem solving in training in Physics "
Author of the dissertation work: Fabien Theophanes Kunis,

I. General description of the submitted materials

1. Details of the documents submitted

The Candidate Fabien Theophanes Kunis has presented a dissertation work and an Autoreferate, as well as a mandatory table of the Department of Physics for the degree "Doctor" according to the Rules of Procedure for acquiring scientific degrees and occupying academic positions at the Sofia University "St. Kliment Ohridski".

An administrative package of documents related to the training procedure in Academic Degree "Doctor" has been submitted in electronic form, with the following content: orders of charging and discharge with the right of defense; Certificate from the Dean of the Faculty of Physics for 6 exams taken according to the individual plan; declaration of authorship of the dissertation work; a similarity report from the electronic plagiarism prevention system available in Sofia University; opinion of the scientific supervisor with the conclusion that the found similarities in the dissertation work are regulated and bear no signs of plagiarism and acceptation of the work for admission to a preliminary discussion of the dissertation work; professional CV; list of publications; author's report on the contribution nature of the work.

The documents from the package are positioned in a request dated 31.5.2023 of the doctoral student to the Head of the Department "Methodology of Training in Physics" for admission to

preliminary discussion of the dissertation work and specifically presented in the electronic format of the package. The doctoral student has attached a document under the title "Author's report on the contribution character of the works", which contains a comparative table of recommended requirements of the Faculty of Physics. The comparative table is in accordance with Appendix 1 for the additional requirements for students for obtaining scientific degrees at the Faculty of Physics of Sofia University and although they are for the professional field 4.1. Physics sciences, it is evident that the document contains convincing authorial defence of the candidate for the scientific degree for the additional requirements of the Faculty of Physics.

The documents submitted for the defense by the candidate comply with the requirements of the Law for development of the academic stuff in Bulgaria, and its Statute and the Rules on the conditions and procedure for acquiring scientific degrees and occupying academic positions at the Sofia University "St. Kliment Ohridski". I believe that the documentation is correct and is an undisputed benchmark for the administrative transparency of the procedure and for objectivity in the preparation of the present review.

2. Applicant details

Fabien Kunis graduated in Bachelor's Degree in Engineering Physics at Sofia University, Faculty of Physics in the period 2008-2012. In the period 2012-2014 he completed a Master's degree in Microelectronics and Information Technologies in the Faculty of Physics of Sofia University. One topic of the thesis for Educational Qualification Degree "Bachelor" is about computer simulations of non-linear processes, and for the master's degree is about cellular automations in physics simulations. The theses he has defended for the bachelor's and master's degrees are authoritative educational benchmarks and are prerequisitions for the sustainable professional profile of the candidate Fabien Kunis and their upgrade to the doctoral degree.

Fabien Kunis builds his professional development from 2013 to 2022 through participation in 14 specialized national and international courses. In synchronicity with his continuous qualification in the specialty, the candidate has been a teacher since 2018 at 125 Secondary School "Boyan Penev" – Sofia in Physics and Astronomy and Informatics and Information Technologies. This teaching experience is not only an exact realization of his qualification as a teacher in 2012, also acquired at the Faculty of Physics, but a convenient and necessary basis for conducting the didactic experiment set in the dissertation.

The applicant's educational status; his accumulated pedagogical experience in secondary school and proven significant professional attitudes and interests to the issues, are a very good

platform for the future academic development of the candidate in the university education in Bulgaria after the successful defense of the doctoral thesis.

3. General Characteristics of the Candidate's Scientific Achievements

3.1. Structure of the dissertation

Fabien Kunis' thesis is 192 pages, of which 173 are the main text. 197 sources are cited, of which 179 are in English and 18 in Bulgarian. The dissertation contains 10 tables and 45 figures, which are listed in Appendix 1.

The dissertation is properly organized into the following structure – introduction, three chapters, conclusion, contributions, list of publications, literature used and five appendixes. There is a good balance in the volume of the three chapters – the first chapter 58 pages, second chapter - 40 pages, third chapter - 33 pages. The introduction is in volume of 12 pages, conclusion -7 pages. Comparatively the larger volume of the first chapter is due to the semantic workload of the chapter, reviewing the questions of team problem solving, on which the information system and its approbation in school education in physics are based. The whole conceptual framework of the dissertation is based on it.

The introduction specifically and correctly describes the design of the study – research objectives and tasks, object, subject and scope of the study, hypothesis and methods of research. Due to the broader conceptual framework, the third chapter is "Research Part", in which the methodology of empirical research is outlined in the context of the whole thesis. I highly appreciate this approach of the doctoral student – to highlight the empirical part of the entire cycle of the cognitive process in the evidential status of the hypothesis.

The advanced hypothesis meets the requirements for development of hypothesis in the specifics of a pedagogical research. The first part contains the pedagogical requirements - appropriately chosen methodology for development of the teamwork skills and implementation in the training in "Physics and astronomy". The second part of the hypothesis is in the expected results – achieving a significant improvement in students' team problem-solving skills. The proof of the hypothesis is in the third chapter of the dissertation based on stratified sampling methods and quasi-experimental method with a control group.

Eight research tasks, resulting from the purpose of the dissertation study, are defined in the introduction. The tasks design a composition in the structure of the scientific work with defensible logic in a didactic study. Each of the three chapters is a separate composite unit in the overall structure. Each chapter with it's name and it's content corresponds to the research tasks, as defined in the introduction. At the end of the first chapter there is a summary part "Conclusion",

thus the author outlines theses with a systematizing nature and makes a link with the next second chapter. It would also be useful to do this at the end of Chapter 2, in order to bring its content into the context of the overall research framework of the dissertation. Perhaps the PhD student's consideration is that this approach is only appropriate in the first chapter of reviewable character and the need to systematize the information in it.

The conclusion of the whole dissertation is in a volume of 7 pages and includes the main results of the study, conclusions from the overall study; conclusions from the 21st century skills concept; for e-learning; for the application of platforms with interactive simulations and perspectives of future research on the subject. It would be appropriate to cover results related to the hypothesis raised.

3.2.Contents of the dissertation

In the first chapter "Team Problem Solving", there are several distinct structures in its composition, structured by a given name, and we can consider them as paragraphs in the contents of the chapter. The overviewed concepts are presented in a deductive plan – a general presentation of the idea of team work; skills for the 21st century; teamwork skills; problem-solving skills; competence for team-solving problems; comparison of existing frameworks for team-solving problems; PISA research in 2012 and 2015, respectively on problem-solving and joint problem-solving.

Chapter 1 is a broad overview of classical and contemporary literary sources of the concepts under consideration. Strong points in the process of reviewing the texts are the demonstrated groups of skills that emphasize the professional erudition of the doctoral student:

- Ability in the circumstantial theses for each notion to discover the meaningful moments, which the doctoral student uses as milestones for the deployment of the research platform in the next two chapters.
- Comparative analysis skills between frameworks and problem-solving concepts /p.43/, between team solution frameworks of CRESST, PISA, ATC215 /p.57/. The comparative table of these models, synthesized by the doctoral student, is a useful detail in development of the research concept.
- Abilities for skillful usage of the data of the Center for Pre-school and School Education in the Results Reports on Bulgaria's participation in the PISA Programme for International Student Assessment. The doctoral student interprets the Bulgarian participation in PISA research in 2012 and 2015 and 2018 in the context of his dissertation thesis. The conclusion that Bulgarian students have serious deficits in the competence to solve

problems and of joint problem solving is a strong argument in favor of the topicality of the dissertation thesis, which has been already argued in the introduction.

- Ability to apply PISA's research toolkit in the design of his didactic experiment. The Competence Matrix for problem solving in collaboration, according to PISA, is a product of two vectors – the problem-solving skill and the competence of teamwork /p.54/. Developed in such a way, the matrix consists of 12 skills, that build competence of collaboration problem solving. This is part of the research design for the assessment procedure for the studied competencies in the third chapter of the dissertation – Research Part.

The second chapter describes the research concept – building of an information system through which team-solving skills to be developed in the students. The concept is evolved in deductive terms in the following compositional units: information and communication technologies in education; computer simulations in training; simulation of natural processes and phenomena by numerical methods and by cellular automation; design of the information system; coding of problem solving skills and of team solving. The good logical connection between the different compositional structures is clearly visible, giving the overall vision of the chapter dedicated to the development of the information system.

The emphasis in this chapter is on the relationship between the two paragraphs – simulating natural processes and phenomena by numerical methods and simulating them by cellular automation. This emphasis was chosen, as it is a good illustration of examples of the logical connection between the different structural parts in the chapter, and as it also justifies the information system developed by the doctoral student in its part for implementation of interactive simulations for team solving of Physics' problems in the educational process.

I would illustrate this with examples in the first part of the selected accent. The beginning of the paragraph for simulating natural processes and phenomena by cellular automation motivates its content by comparing it with the Runge-Kutta method, giving good results, comparable to experimental ones, by solving differential equations. The doctoral student describes the construction of a cellular automation by which the Lotka-Volterra model is simulated. The square grid has 10000 cells as statistically significant is this size, and allows a wide selection of different configurations. The multiplicity of the cell states has three predicaments: when the active cell is empty (environment), when the active cell is a predator and when the active cell is a victim. The rules for accurate simulation of the predator-victim system are defined and the doctoral student has taken into account the shortcomings of the Lotka-Volterra model in these rules, mentioned at

the end of the paragraph. Encoding of the rules for empty cells, predators and victims has been presented. As a result of the implementation of the program, in Figure 2.7. simulation of the model of Lotka-Volterra is shown, with a cellular automation at different time points from 0 to 220 in 20 time steps. Figure 2.8. shows the populations of victims and predators as a function of time. The comparison between this theoretically constructed graphic and the graphic in Fig. 2.4 of the Hudson-Bay leather coat company's experimental data, leads to the conclusion that the developed model, using a cellular automation correctly, simulates the behavior model of the victim-predator system. The result, significant for the dissertation, is that it is possible to simulate natural processes by cellular automation.

In the following paragraphs of the second chapter, the design of the information system has been described, as first the system is presented in a test mode, then in a problem-solving mode, with interactive simulation of natural processes – gravity with simulation "The Falling Apple" and harmonious vibration with the simulation "Mathematical pendulum". The approach, illustrated by the two simulations cited, coincides very well with the approach used in the PISA 2012 study with the following stages in the problem-solving process: identification of the problem and understanding of its nature; presentation and enunciation of the problem; deliberate planning and implementation of the plan; feedback in the implementation of the process. Thus, covering specific knowledge (p. 103 of the dissertation) for two different areas of mechanics, the doctoral student justifies the importance of competence in the problem-solving process. In this part, the doctoral student did not describe the above mentioned stages, but in the next part, which is about the team solving problems for the mathematical pendulum and for connecting consumers in an electric circuit, this has already been done, with the stages visualized in 10 figures per screenshot in the process of the solution. For the team solving problems, the information system is built into two modules. The first is a virtual chat where the student communicates with computer agents and develops teamwork skills. The second module is an interactive simulation of a physical process or phenomenon. These two modules are present at each stage of the team solution to the problem – in the left panel is the dialogue between the computer agents on decisions on the sub-problem of the task, and in the right panel is the interactive situation, related to the sub-problem discussed.

The doctoral student has selected a suitable problem related to the mathematical pendulum and with resources for teamwork: the determination of each of the magnitudes on which the period of the mathematical pendulum does not depend and on which the period of the mathematical pendulum depends is a logically distinct sub-problem, to which there is an interactive simulation and a situated dialogue student-computer agents. I believe that this approach for the logical decomposition of the main problem in sub-problems and their interactive simulation

is appropriate not only in the field of physical knowledge, but also in other areas of the natural sciences studied in the school system. This is one of the contributions of the dissertation. Methodologically interesting is the idea of the doctoral student, that the students with increased interest should derive the formula and compare it with the experimental data from the simulation. The approach described is also repeated for the equivalent connection of sequentially connected consumers. .

The scientific results achieved in Chapter 2 would be more visible if the doctoral student would include one final paragraph, discussing research tasks № 4 and № 5, as mentioned already in the introduction. This conclusion would be a good transition to the third chapter.

Chapter three is "Research Part". In the beginning, objectives, tasks and research questions are presented. While in the introduction the research tasks are presented in a very concise and clear of detail manner, this chapter contains a detailed description of the research issues and their respective tasks. Perhaps it would be more appropriate if the four questions of the research were referred to in the beginning of the first and second chapters of the dissertation, because they have been developed precisely in these first two chapters, and they are also parts of the design of the overall study. Perhaps the doctoral student has other considerations to include all research questions at the beginning of chapter three .

The essential part of the third chapter is the practical implementation of the developed information system in the educational training process in "Physics and astronomy" in the seventh, eighth, ninth and tenth grade in 125-th Secondary School "Boyan Penev" in Sofia. In the methodology of this empirical study, methods and tools of didactic research are reviewed , but only in the context of their exhact application in the study of the doctoral student. The didactic experiment was correctly organized – eight classes, of which six-humanitarian and two mathematical. Each of these classes is divided into two groups – one is control and the other is experimental, in which the information system is implemented. The sample is sufficiently representative: the experimental group was 132 students, and the control group -154 with almost equal participation of girls and boys in both groups. One example is given in the training experiment – the simulation "The Falling Apple" and the way of evaluating the answers in it.

The constructed criterial system of 12 indicators/skills/ is of evidential status, resulting from the matrix of skills, forming joint problem-solving, described in the first chapter. Page 55 directs to the correct construction of the verification procedure, regarding the hypothesis of the didactic experiment. The numerical values for each indicator are derived from the 2015 PISA methodology. The answer to each question is encoded with two categories zero or one/0,1, dichotomously/or with more categories from zero to n/0,1,... n, politomously/. Synthesized in

Figures 3.2 to 3.8, processed results of the experimental and control group are presented – initial test and final test – descriptive statistics and distribution of the individual sub-competences of competence for team problem-solving. For each skill a variable of its statistical quantities are correctly calculated – fashion, median, standard error of mean; confidence intervals for the average; standard deviation; variance coefficient and range of minimum and maximum estimates, and are arranged in the quoted figures. Annexes 2 to 5 are a detailed database of the values of each indicator and for each test done by the control and experimental groups in the input test and in the final test.

The discussion of the results is in several plains for comparisons, significant to prove the hypothesis. The mean values for each of the skills of the control and experimental group, as well as their standard deviation, shall be compared. There are significant results suggesting a deviation from normality for all skills from A1 to D3 in the initial and final test for both groups through Shapiro-Wilk's normality test. Therefore, the Mann-Whitney U test is selected, as an appropriate average equality test, without checking the parity of the dispersions. A T test with a one-sided criterion for independent samples was used. The purpose of this test is to determine whether there is a statistically significant difference between the control and the experimental groups before and after the introduction of the experimental factor-learning with the implemented platform. The results are presented in Table 3.4. In column **W** is the statistics of Mann-Whitney, as the data is not normally distributed, and the **p** value determines whether there are statistically significant differences in the results of the control and experimental groups. This value determines, that in the final tests marked as "post test", there is a statistically significant difference between the two groups in favor of the experimental group. This means that the zero hypothesis is rejected and the alternative hypothesis is assumed, that the mean values for the control group are lower than those of the experimental group, and that this is statistically significant. The magnitude of the effect of the Mann-Witney U test differences is determined by the rank biserial correlation, the values of which are also in Table 3.4. By the values of the rank correlation, the doctoral student makes a qualitative analysis of the effect of the system on the studied skills. The highest correlation value has the ability to complete tasks undertaken by team members, followed by skills to identify tasks and allocate them to the team and according to skills, according to the feedback skills of the team members, and according to the skills to assess the results of solving the problem. The lowest is the coefficient of skills to implement the plan.

Differences in the results of girls and boys in the experimental group were studied. For 7 of the variables, the Shapiro-Wilk test demonstrates a normal distribution in both groups and Student's Average Equity Test has been selected, and for the others the Man-Whitney test is used

for a deviations from the normal distribution. It has been proven that the differences in the performance of girls and boys for ten of the variables /skill groups/ are decreased, and for two of the variables, the differences are increased – in understanding the essence of the cooperation, formulation of the objectives, as well as in compliance with the accepted rules for participation in the team. Interestingly, the doctoral student commented that in the initial tests those of girls scored higher than those of boys in joint problem-solving competence, which corresponds to the results of PISA 2015. However, when using the training platform, these differences decrease.

The conclusions of Chapter 3 p. 151 emphasize that the dissertation study complements the PISA matrix for the skills that builds competence for team problem-solving, but for problems defined by Physics. Conclusions have been drawn for the better results of the implementation of the developed information system for teamwork skills; to solve problems; for team problem solving and for the higher level of mastering the competence for team problem-solving. These conclusions need more convincing evidence through qualitative analysis of the responses and the process of work of students when applying the information system in the course of empirical research. Thus, they would be freed from declaratoryness and would emphasize the resultant part of the raised hypothesis synchronously with the excellent statistical confirmation of the hypothesis.

2. Scientific publications included in the dissertation

The doctoral student's publications based on the work on the dissertation are published in 7 co-authored papers and are reported in 18 reports at international and national conferences, of which 6 independently and 12 in co-authorship. Some of the individual reports are at authoritative international forums - Harvard Summer 2021, International Physics of Living Systems- France, Harvard University. A complete list with bybliographic description of the publication is annexed to the Thesis and to the full package of procedure documentation.

It is not indicated whether all publications participate in this procedure.

The doctoral student Fabien Kunis has attached to his documents an Author's report on the contribution nature of the works, which contains a comparative table of the criteria of the Faculty of Physics of Sofia University for publications for the acquisition of the EQD "Doctor" with those of the candidate. For the criterion 'Minimum 2 publications, of which at least 1 is from Group I or Group II', the doctoral student shall indicate **4 publications**. On the criterion for participation in at least one conference with a report, the doctoral student indicates 18. My assessment is that the publications included in the dissertation work meet the minimum national requirements (under Article 2b (2) and (3) of the ZRASRB) and, respectively, with the additional requirements of the Sofia University "St. Kliment Ohridski for acquiring the educational and

scientific degree “Doctor” in the field of higher education “Pedagogical Sciences” and professional field “Pedagogy of...”

In this first procedure for the candidate, there are no repeated publications from those in the dissertation. There is no plagiarism proven by law in the presented dissertation work and in the autorepherate.

4. Description and assessment of the applicant’s teaching activity

In accordance with Article 59 (2) of the PURPNSZADSU, after passing the examinations according to an individual plan, a full-time doctoral student is assigned to a full-time doctoral student 45 hours per year. In the documents of the procedure there is a certificate signed by the Dean of the Faculty of Physics that the doctoral student Fabien Kunis has successfully passed all exams according to the individual plan and has been assessed positively throughout all years of study. We accept that this document certifies that the doctoral student has completed the educational and pedagogical activity set out in the individual plan and positive attestations. There is no other information in the documents to assess the educational and pedagogical activity of the doctoral student.

5. Relevance analysis of the scientific and applied achievements of the candidate contained in the materials for participation in the competition

I accept the contributions that the doctoral student has set out on page 159 and complement them without repeating them. In my analysis in 3 of this review, I pointed out some contributions, placing them in order to support them in the specifics of the evidence for the achievements of the doctoral student and for convincingness in my summaries as scientific and applied contributions.

Scientific contributions:

- Detailed conceptual system through high literary awareness of the doctoral student for problem-related training and its implementation in a model for team problems solving in the educational content of Physics, as well as in other areas of natural science.
- Proposed new approach to solve problems, with broad applicability in different areas of natural science, through decomposing them into sub-problems for which training interactive simulations are developed.
- A comparative analysis of the international frameworks of PISA, ACT215, CRESST for implementation of competence for team problem-solving and based on the comparison was made a reasonable choice for the methodology of PISA for the development of the information system and its toolkit.

- Proven cycle of scientific knowledge in the field of methodology of training in natural sciences with theoretical and empirical components designed to the research hypothesis in both parts of it: the pedagogical conditions-appropriately chosen and implemented methodology in the training in subject “Physics and astronomy” and the resultant part of the hypothesis: improved problem-solving skills in a team.

***Scientifically Applied Contributions*:**

- Completed the PISA matrix for the skills that build competence for team solving problems, but for the field of physical knowledge and based on it, an applicable critical system has been developed in the didactic experiment for approbating the information system for this and its improvement.
- Skillful usage of JASP statistical software and provision of prove of its applicability to pedagogical research.
- Didactically designed and implemented resource of information systems for comparison by students between the theoretical conclusion of a formula for physical process and experimentally obtained data from its interactive simulation in the system

In the attached materials there is no information about citations and the personal participation of the doctoral student in collective publications.

6. Critical comments and recommendations

In the analysis in the present review in item 3, specific critical notes have been made and here I synthesize, without repetition of the text, but I would provide arguments, if necessary.

- There is a necessity for more clearly described link between simulation of natural processes and phenomena by numerical methods or cellular automation and the development of simulations in the training information system. This is significant for the conceptual framework of the interactive system and in the choice of methodology relevant to the hypothesis.
- There is a necessity for outlining the contents of the chapter and the transition to the next chapter at the end of the three chapters; the need to refer some of the planned research tasks at the beginning of Chapter Three to the previous chapters. This would emphasize the available logic in the dissertation study.
- The conclusion of the dissertation would have a stronger finalizing resource, if the leading accents in it were linked to a relevant research task and to emphasize its development in the dissertation work and in the internal logic of the dissertation structure; the evidence of

the research hypothesis through qualitative and statistical analysis should be further highlighted .

- Technical notes: the use of markings only in Cyrillic or only in Latin for the skills in the matrix; more precise use of "figure" or "table".

7. Personal impressions of the candidate

I have no personal impressions of the doctoral student Fabien Kunis, except for valuable dissertation work and precisely presented materials on the procedure.

8. Conclusion: After familiarizing myself with the presented **thesis paper, Auto-referate and other materials, and on the basis of the analysis of their significance and the scientific and applied contributions contained therein, I confirm that the scientific achievements meet the requirements of the Law for development of the academic stuff in Bulgaria and the Rules for its Application and the relevant Regulations of Sofia University "St. Kliment Ohridski" for the acquisition of the educational and scientific degree "Doctor". In particular, the candidate fulfills the minimum national requirements in the professional field and no plagiarism has been established in the thesis, the Auto-referate and the science papers presented in the procedure.**

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

II. TOTAL CONCLUSION

Based on the above, **I recommend** the scientific jury to award **the educational and scientific degree "Doctor"** in the professional field "Pedagogy of Education in …" to

Fabien Theophanes Kunis.

09.. 2023.... Author of the review: Prof. PhD. Todorka Stefanova