EVALUATION OF A BLEND TEACHING MODEL BASED ON FLIPPED CLASSROOM AND STEAM APPROACH TO BOOST APPLIED SCIENCE CONCEPTS UNDERSTANDING IN TECHNOLOGY EDUCATION

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Abstract

This research focuses on the evaluation of contemporary didactic approaches, at Secondary level of Technology Education, for electricity concepts and electrical circuits. Our proposed hybrid-teaching model, is based on good practices of flipped classroom and STEM approach, for which, to the best of our knowledge, there are not much research data. To this end, our model takes into consideration the personalized learning needs of every student, sets specific learning goals to help each student improve his understanding for applied science STEM concepts. This paper highlights the importance of personalized teaching, but also collaborative methods, which promotes students' creativity, cognitive skills and enhance their learning capabilities. Our model promotes real experiments and the use of specialized software during learning process to analyse data and draw conclusions. Our initial statistical results reveal that our blend proposed model improves students' ability to understand science concepts and promotes computational thinking skills.

Keywords: STEM, Flipped classroom, Applied Sciences, Innovative Learning, Educational Technologies, Computational Thinking

1 INTRODUCTION

The ultimate goal of applied teaching approaches is to improve the quality of teaching at all levels of educations. This is achieved through systematic theoretical research, together with practical applications and emphasis on the investigation of natural phenomena, to familiarize students with the laws of nature. According to several researches, conducted over the past two decades, highlight the important role of inside – classroom teaching and its contribution to the improvement of students' cognitive and emotional levels [1]. However, the main research goal is how to achieve a more effective teaching methodology, which results in better students' performance. In most of the cases, a successful teaching methodology is the one, which cultivates essential teacher – student communication, and leads to students' cognitive and academic development and guarantees certain performance outcomes.

In order to address specific learning difficulties regarding the understanding of Natural Science concepts and phenomena, most of the educational interventions are based on learning theories, which adopt contemporary teaching methodologies, didactic models and tools, as well as modern performance evaluation methods [2]. In this paper, we propose a hybrid – teaching model, based on good practices of flipped classroom and STEM approach, with a focus on concepts of electrical circuits. Our model is tested and evaluated and our initial statistical results reveal that flipped classroom teaching techniques with contemporary web 2.0 tools significantly improve students' ability to better understand circuitry concepts and develop computational thinking skills.

2 LEARNING BY DOING

In order to prepare our students for the 21st century society, in which the 4th Industrial revolution influence economy, we need to apply a more technologically advanced and learning – friendly way teaching approach. To this end, research on modern learning theories and constructivist teaching methodology is vital. In many schools, older teaching methodologies are applied, which does not give students a more holistic way to learn by solving actual and real scientific problems. In STEAM approach, students work in groups and their learning goal is set by solving a multi – disciplinary problem. According to [3][4][5], the project – based learning methodology is a prevailing approach. In most of the cases, students follow a constructivist learning approach, as if they belong to a group of professionals [6]. Thus, students gain a deeper understanding and cognitive skills when they are actively engaged with real – world problems. Moreover, studies in [7] reveal that students do not properly conquer the deep meaning of scientific ideas, in cases they act as passive information receivers.

In essence, information is translated quicker into knowledge, in cases when students engage themselves in constructions, i.e. in cases when they construct their own knowledge by using artifacts or physical computing materials [8]. In those cases, students really built their own knowledge by acting as active scientists, or artists or historians etc. A teaching model based on project based learning, supports students' inquiry skills and their ability to ask and test new ideas and approaches. Surveys, as in [9] and [10] has shown that students achieve better performance when they program a robot, or when they design an artifact, as compared to the traditional teaching model of passive learners. In this paper, our work focuses on applying contemporary hybrid teaching model for science and technology subjects. Our approach supports constructions and experimentation during learning process. Students may also combine their previous knowledge and experience, in a unified constructive framework, which allows them to make more robust conceptual connections, and test their models as candidate problem solutions [11].

3 COMPUTATIONAL THINKING AND STEAM

The term "*Computational Thinking (CT)*" in education appears in [12], with a reference to Logo programming language for children. Papert once said: "*I believe that some used of very powerful technology and computer ideas can offer children new opportunities for learning, thinking and emotional development".* Papert's vision begun to come true after two decades, when computers gained the necessary power and became portable. Computational thinking, as a basic STEAM pillar, indicates that students will work with data, will be able to understand the emerging patterns, will apply the "*divide and conquer"* problem – solving approach and will think algorithmically [13][14]. Today, it is widely recognized that CT offer an applicable set of skills that can help students in several STEAM areas, ranging from astronomy to history. CT skills do not develop only computer scientists, but everyone who can think algorithmically. CT is considered a cognitive skill for everyone, offering the tools for problem solving and promoting creativity [15].

CT helps students to better understand, the nature of a scientific and technological problem, when they need to confront new problems. The term of CT officially launched in 2006 in [16] and it is used to describe the following phases:

1. The 1st phase has to do with the decomposition of a problem into smaller parts. This is based to the philosophical principle of "*divide and conquer".* In that case, students familiarize themselves with the main ingredients of the problem and try to integrate the partial solutions into a unified one, for the initial problem.
2. The 2nd phase has to do with the pattern recognition and definition in data representations or data structures. In this case, students observe emerging and repeated data patterns and try to interpret them, by finding similarities, regularities or deviations.
3. The 3rd phase has to do with the generalization or abstraction in order students to understand the overall nature of the problem. Students try to model the patterns of the previous phase and construct the model to solve their problem.
4. Finally, in the 4th phase, they design and test their algorithm (i.e. solution), ensuring that they take into consideration all necessary data and applying all scientific principles. That phase has to do with the programming and/or construction of an artifact and the testing of their solution under experimentation.

The widely known optical programming tools, such as Scratch, Blockly and mBlock, are programming environments that can promote CT dimensions. Moreover, CT is not to be confused with computer science, even if CT's phases include programming, algorithmic skills and mathematical thinking. In the present study, students use some of these tools to provide solutions. The main goal of using a programming language is to properly analyze data and approach the solution of a problem in polynomial time. Moreover, optical programming languages are popular to K-12 students to use them in serious game development, data science, music, etc. [18][19]. The use of optical programming motivate students from eight years old to write code easily [18]. According to [20], students between 10 and 12 years old show a preference to solve mathematical problems through coding. In [21], Ke et. al, engaged secondary education students with game design and programming for mathematical problems and noticed that students develop positive attitude towards learning mathematics in a fun way. In addition, this method was beneficial for activating students' reflection on the mathematical experiences of their daily lives.

It is proven that the use of programming blocks in computer science courses can promote students' cognitive level and self – efficacy and lead to less learning stress, especially when they are engaged in designing a new program [22]. Therefore, block programming (i.e. Scratch, App Inventor) maintain learning motivation and enhance students' interests for knowledge and experimentation [23]. In [24] authors apply Code Club (available at: https://codeclub.org/en/) to primary education students and confirm their enhanced interest towards computing.

4 FLIPPED CLASSROOM AND LEARNING STYLES

Each student has their own learning style, and the way in which this is achieved, is a crucial factor for the classroom's learning curve, for the following reasons:

1. It enables teachers to devise the appropriate teaching and counseling interventions, which correspond to the learning style of the students, in order to achieve the best learning outcomes.
2. The teacher's information about the his students' learning styles, affects his attitude towards their personality differences, cultural experiences and cognitive deficiencies. To this end, differences among students constitute customizable learning environments.
3. The different ways in which students learn, interact and process information, help teachers shape their teaching method, in such a way that all students have equal opportunities for success [25].

According to [26], as soon as each student is aware of his personal learning style, he is more motivated to learn, acquire and retain knowledge for longer periods and show greater autonomy in learning. The selection of the appropriate teaching strategy, to actively support students' learning styles, is a difficult and challenging task. Applying differentiated teaching styles, in real time, is very difficult to achieve in practice, as there is a high possibility students may not adapt and didactic noise will start to appear [27].

4.1 Flipped Classroom Application

The 21st century digital technology opens wide windows into knowledge for students, which is accessible through Internet connected gadgets, computers, tablets, smartphones etc. [28]. In that way, students interact among each other in many ways, share ideas and join study groups. Currently, in the COVID-19 era, students continue learning via teleconference methods and via blended learning. According to [29], the digital information age gives students access to many shared learning resources, like video-recorded lessons, MOOC lessons and digital libraries. Consequently, under this premise, the "traditional" teaching model in which students only listen and not create, is no longer viable [30].

According to [31], several student activities, like extra lecturing, labs and other projects, could be equally well be implemented with Web 2.0 tools, such that students could learn in their own pace. In [32] authors support using Web 2.0 tools in learning process, which help create and maintain collaboration and interaction that last long. To make a long story short, digital technology help students learn any time any place by developing collaborative skills. Therefore, the digital age offers equal opportunities for students to both learn individually and at the same time cooperatively inside a classroom. This blended scenario assumes that students develop digital and soft skills at the same time. To this end, flipped classroom has become one of the most attractive teaching methods in K-12 education and may considered a model for practical teaching and learning which promotes customized and active learning, both in secondary and academic education [33].

In [34] authors note that flipped classroom has features of blended learning, integrating both the face-to-face teaching inside a classroom and the distant learning outside it. This means that students could continue building their learning curve, at home, via watching certain asynchronous video lessons, utilizing online cooperation. Flipped classroom is considered as the integration of teaching and learning that combines both physical presence and distant learning [35]. It is also a student – oriented approach, in which students have an active role inside classroom. In this case, the teacher's role is to consult and motivate students, to guide and give them feedback [36]. With flipped classroom, students do not need to spend much time to long lectures, rather work on finding the solution to problems at home. The application of flipped classroom also contributes to a better understanding of the use and necessity of digital technology during teaching and learning. This means that both teacher and student use the same digital tools during teaching [37].

The study of flipped classroom is based on Bloom's revised cognitive classification theory. This classification provides six levels of learning, as depicted in Fig. 1. The layering explanation is as follows (down to up explanation):

1. **Remembering:** In this level, students try to recognize and recall information. They also try to understand basic concepts and context principles.
2. **Understanding:** In this level, students try to prove the depth of their understanding, to interpret all information and to summarize.
3. **Applying:** In this level, students practice and apply their knowledge to design the solution of a given problem.
4. **Analyzing:** In this level, students use their critical thinking to solve a problem, discuss and compare their findings with peer – students and write a summary. During this process, students gain fresh knowledge and share ideas among group activities. In this level, students apply computational thinking.
5. **Evaluating:** In this level, students evaluate all learning concepts and asses if they deviated from their learning goals.
6. **Creating:** In this level, students are able to design, built and produce a new learning outcome. In flipped classroom, the first two levels (two lower levels) of cognitive classification are practiced outside of class time [38]. Inside classroom, students focus on the three higher cognitive levels, in which teacher's role is to consult.

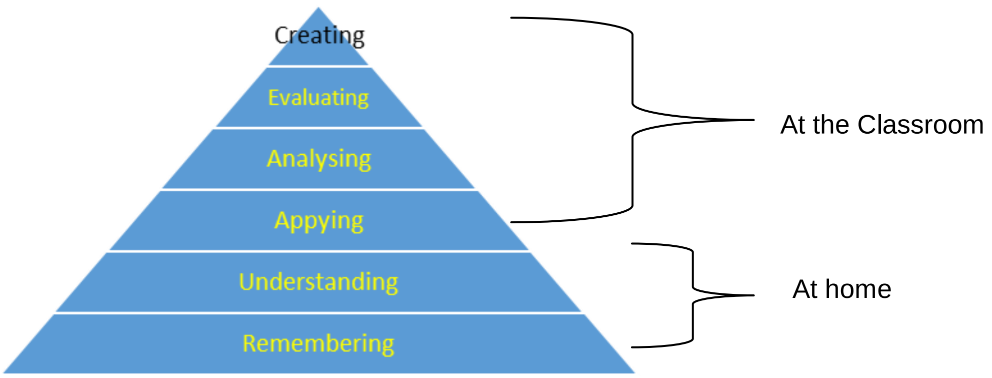

Figure 1. Bloom's revised classification [39].

4.2 Learning Benefit and Motivation

With the flipped classroom model, low performance students can better interact with new knowledge and at their own pace. Digital material, simulations and experiments provide fundamental support for individual learning, so that inside classroom students devote their time to higher cognitive levels of learning. In flipped classroom, students work their way up, from the lower level (i.e. remember) up to the highest level (i.e. create) [39] and focus on how to conquer this level. Additionally, authors in [40] state that classroom activities and project – based learning, should focus on creations and how to reach the higher cognitive levels, in versus of the traditional teaching model which is based only to lecturing.

According to [41], students' understanding in several cognitive contexts, within flipped classroom, are better as compared to the results derived from a conventional classroom. Moreover, the students' perceptions towards the learning environment is improved. Authors in [42] conduct a study to explore how digital technology can be used in flipped classroom to boost students' understanding. According to their findings, the use of technology is effective and scalable in a hybrid-learning environment, which leads to better grades. Following, studies focusing on measuring the pre – test evaluation and post – test evaluation show that students statistically improve their learning curve in flipped classroom model [43]. This view strengthens the necessity for a hybrid – learning, self – paced and digitally supported environment. In [44], authors observed that flipped classroom model for computer science and calculus subjects show excellent results in terms of evaluation, as compared to the traditional teaching approach, and is worth the time and effort put from teachers. It is worth saying that through flipped classroom, teachers could easily assess students' learning goals, while students understand their need to overcome their learning deficiencies. Additionally, the ability to pause and watch video lectures on demand, positively affect students' effective learning [44]. According to [43], flipped classroom methodology increases students' self – perception and self – efficacy in learning.

Therefore, the learning environments created by flipped classroom highly meet students' needs towards autonomy and thus triggers higher levels of motivation [45]. Similarly, in [46], students' active engagement to projects is a result of the motivations created for them. The term "commitment" is often used to describe students' active learning and desire to participate in team activities [47], as defined by the teacher. Studies, as in [45], has shown that students who have been involved in flipped classroom activities, are more eager to participate within classroom activities, after watching and exploring the online digital curriculum (i.e. video lectures, MOOCs material, etc.). In that way, students feel more confident inside the classroom, because they have already been prepared for the lesson. This means that they have already been exposed to the basic and fundamental knowledge for their daily lesson. This cognitive lead enhance their involvement in-group activities; support their participation in group discussion and problem solving procedures.

Flipped classroom also promote students' empowerment, development, commitment and critical thinking. According to [49], students are satisfied with their overall progress, as soon as they used web 2.0 tools and programming to acquire the basic prerequisite knowledge at home. Similarly, according to [48], students achieve deeper understanding of multi – disciplinary subjects and are confident in approaching a problem solution. Overall, from the majority of research findings, we realize that flipped classroom supports students' active participation, boost their confident and enhance their critical thinking. In contrast, mere lecturing tends to promote a passive attitude towards learning and has many drawbacks. For example, the majority of materials and activities focus only on a particular book, lecture, and disengage students from active participation and problem solving. In that case, students mainly reproduce information and do not transform it into knowledge [50].

5 RESEARCH DESIGN AND METHODOLOGY

Our pilot study results derived from the participation of 80 secondary education students, which were engaged in learning activities that concerns electrical circuits and artifacts. We also took into consideration gender criteria, so the following groups concern 50% boys and 50% girls:

1. **Control Group (CG):** Students in this group only listen to lecturing and given a certain problem, the solution of which concerns the construction of an artifact.
2. **Team A Group (with Web 2.0 tools):** Students in this group only listen to lecturing and additionally use virtual labs software and web 2.0 tools to better familiarize themselves with circuitry problems.
3. **Team B Group (with Web 2.0 tools and Flipped Classroom):** Students in this group follow the flipped classroom approach and according to Fig. 1, acquire the prerequisite knowledge working individually at home. Inside classroom, they also use Web 2.0 tools, software and hardware (i.e. Arduino, Raspberry, sensors and LEDs), to solve a particular problem, concerning circuitry. They also program their circuitry with block coding (i.e. optical coding). In order to familiarize themselves with circuits and boards, they design simpler circuits in TinkerCAD (available at: www.tinkercad.com)

5.1 Research Implementation

The research focuses on didactic interventions related to the understanding of electrical circuits and applied science problems concerning electricity. All students participated on a voluntary base and divided in (3) distinct groups, as aforementioned. In all groups, students explore the potential of designing and constructing models, to better understand electrical circuits. Especially, Team A and Team B also used virtual lab software and web 2.0 tools. On the contrary, control group's teaching methodology is mainly based on teacher's lecturing and exercises using blackboard. To test students' comprehension, we used D.I.R.E.C.T (*Determining and Interpreting Resistive Electric Circuits Concepts Test*) worksheets and questionnaire for electrical circuits, available at [54].

Technology teachers' experience is considered valuable for the design and implementation of our proposal and intervention. Students informed regarding the (3) groups and the way interventions will take place in each one and having the consent of the school Principal, technology teachers agreed to participate as well and follow our proposed didactic approach, customized for each aforementioned group. Especially, students in Team A and Team B, further divided in sub – groups of 4. We try to keep group and sub – group diversity as high as possible to succeed in making optimal student and study groups matching. Moreover, all groups were taught the same circuitry principles and were given the same questions and same problems to solve. All groups have access to the school's lab materials and especially Team A and Team B use software and sensors from TinkerCAD App.

Initially, students were given the D.I.R.E.C.T. v.1.1, as a pre-test, which was translated in Greek language. The main purpose of the test is to record the level of potential prior knowledge and/or attitudes towards the subject of circuitry, that students may have. The pre – test have 29 in total questions, as appears in [54]. Afterwards, a series of experimental activities based on worksheets followed, in order to determine the necessary time needed for the completion of all activities, the adequacy of the available materials, as well as to record any deficiency in materials. This phase clearly enhances students' computational skills and ability to experiment and interpret data accordingly. Finally, students were given the D.I.R.E.C.T. v.1.1, as a post – test, with the goal to detect the level of improvement regarding conceptual understanding in circuitry problems. Under no circumstances, did we give any feedback to students regarding their initial answers for the pre – test.

5.2 Results and Discussion

In this section, we record the plots regarding the students' answers to both tests, before and after the intervention. Moreover, pre – test results reveal that both boys and girls share the same prerequisite cognitive ideas. In the following tables (Table 1, Table 2, Table 3), we depict results regarding the correct answers given by boys and girls in Pre and Post Test correspondingly for CG, Team A and Team B groups. We also give the percentage as compared to the total answers given, for boys and girls. We clearly observe that in all groups the percentage raises, after the teaching intervention, as appears from the post – test results.

Table 1. Control Group (CG) Results

	Correct / Total Answers (%)	
	Pre - Test	**Post - Test**
Boys	47 / 348 (**13,5**)	75 / 348 (**21,5**)
Girls	44 / 435 (**10,1**)	71 / 435 (**16,32**)

Table 2. Team A (Web 2.0 Tools) Results

	Correct / Total Answers (%)	
	Pre - Test	**Post - Test**
Boys	45 / 406 (**11,08**)	99 / 406 (**24,38**)
Girls	43 / 317 (**13,56**)	93 / 317 (**29,34**)

Table 3. Team B (Web 2.0 Tools and Flipped Classroom) Results

	Correct / Total Answers (%)	
	Pre - Test	**Post - Test**
Boys	47 / 348 (**13,51**)	119 / 348 (**34,20**)
Girls	43 / 464 (**9,27**)	123 / 464 (**26,51**)

According to the data from the aforementioned Tables, we clearly observe that there is a considerable improvement regarding the correct answers between pre and post testing for both genders. We also observe that better results succeed students who belong in Teams A and B and in particular, Team B members, who follow our flipped classroom blended teaching model. To this end, flipped classroom give space for experimentation, which helps students' raise the total correct answers. This result is obvious from Fig. 2, for both boys and girls

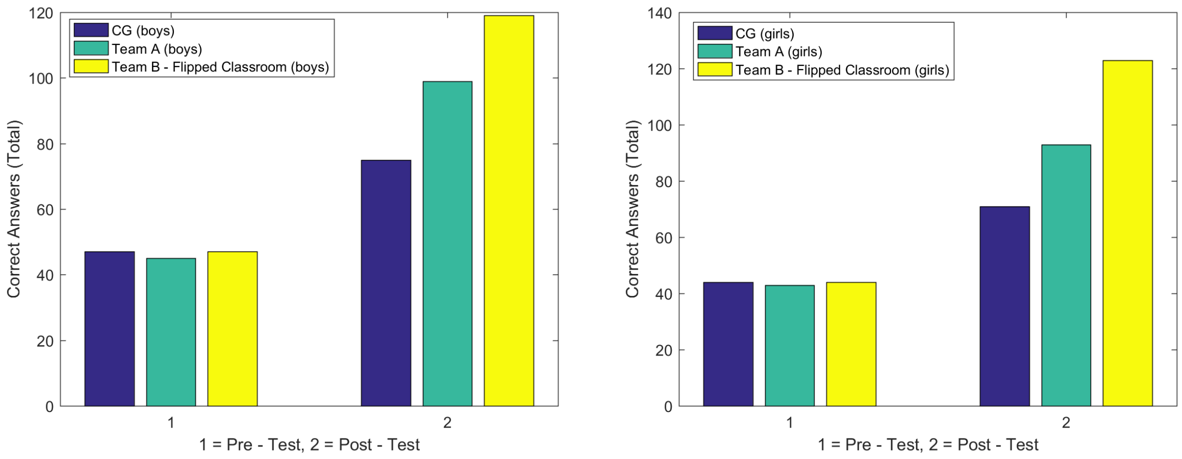

Figure 2. Boys (left plot) and Girls (right plot) performance for CG, Team A and Team B

An important result is that the combination of flipped classroom with web 2.0 tools and software, leads to better results that depict the deeper understanding towards circuitry. In Fig. 3, we give snapshots from the collaboration and experimentation phase of Team B members.

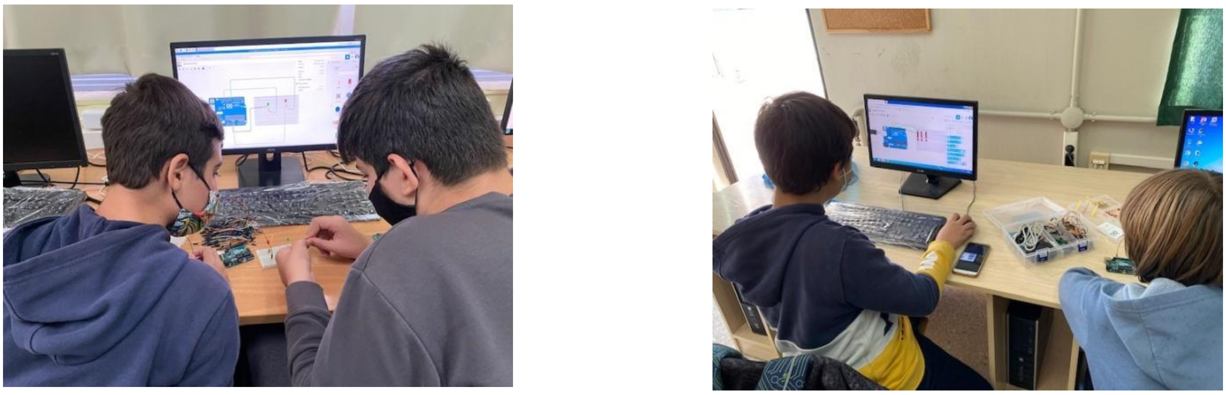

Figure 3. Experimentation and Collaboration for Team B members

Moreover, according to students' answers regarding Team B in post – testing, the standard deviation of wrong answers is lower, which means that students may answered wrong, but did not give an answer by luck. Probably they misunderstood a part of the particular question.

6 CONCLUSIONS

In this paper, we recorded attitudes, correct and wrong answers of 80 secondary education students, both boys and girls, regarding applied science and technology questions with a focus on understanding electrical circuits. During the process, all sufficient materials were available to all participants. We propose and test a hybrid – teaching model, based on good practices of flipped classroom and STEM approach for learning basic circuitry. Our model takes into consideration every students' personalized learning needs and sets specific goals to help the student improve his understanding of applied science topics. To this end, our research divides students into three groups, and evaluates their progress through pre and post D.I.R.E.C.T testing. In this study, we achieve STEM integration in content teaching based on interdisciplinary approach, with a balanced focus on each of the STEM disciplines and dimensions. We also support the inclusion of computational thinking as an appropriate methodology for integrating models and simulations into the classroom, considering a mixture of computational and real experimentation, with real circuitry data. Therefore, students may collect, analyze data, and apply *divide and conquer* method to decompose a problem, solve its sub – problems, and integrate the solutions to solve the bigger one. They are also involved in coding and prototype circuit creation and testing. This attitude increases students' self – confidence and reduce school dropping out.

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