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Original Paper

Application of Flipped Classroom Methodology in Applied Sciences through STEM Exploitation Activities during COVID Pandemic Period

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Abstract

Differentiated instruction is an approach that presupposes the existence of a diverse number of students and their ability to access knowledge provided that a variety of methods and activities is used. Differentiated instruction is a way to incorporate and diagnose the individual needs of every student separately and to create such a learning environment so as to cover all needs. All students are not the same that means that they learn in different ways and at a different pace. Based on this knowledge, differentiated instruction applies an approach both to teaching and learning that offers the students a variety of choices to gain information and better understand the newly acquainted knowledge. Differentiated instruction is a teaching approach based on the principle that all teaching techniques must vary and adapt accordingly in relation to the needs and the various ways of learning on the part of the students with the view of enhancing the understanding of knowledge within the classroom. The model of differentiated instruction proposed requires on the part of the teachers to be flexible in the technique they use and adaptable in the curriculum and in the presentation of the information based on the needs of the students. Based on the idea that change in teaching practices may help overcome the ineffectiveness of the educational systems and their inability to cover the needs of the students, it is considered necessary to examine whether the use of differentiated instruction learning approach could improve the understanding of the students in the fields of applied sciences.

Keywords

differentiated teaching, flipped classroom, STEM, computational thinking, innovation

1. Differentiated Instruction as a Teaching Method for the Elimination of Exclusion

According to the international teaching standards, differentiated instruction is the vehicle through which a number of schools frame the teaching component of cohesive practices (Jarvis, Bell, & Sharp, 2016). Contemporary research articles present differentiated instruction as an answer to the inevitable diversity within any classroom and therefore are correlated with the full spectrum of students at any level. It is sometimes interpreted as a single uniform teaching approach or a collection of teaching strategies for the reinforcement of teaching. (Taylor, 2016)

The differentiation of instruction can be comprehended with at least one of the following ways:

a. As a complete and systematic approach to deal with the needs of the students' diversity in mixed ability classes which aims at the tackling of the different levels of learning readiness on the part of the students.

b. The students' interests should be pertinent to the content of the curriculum in order for the students to be encouraged and motivated for their further commitment to learning.

c. The differences in the students' preferences dependent on the content in order to exploit their abilities to the fullest (Tomlinson, 2014).

The effectiveness of a differentiated approach is based on a series of interdependent thorough teaching methods that guide the whole class dynamic. They include a high-quality curriculum which is organized around clear learning aims and demand a dynamic differentiated design. That means flexible cooperative practices, appropriate homework for all students and a positive learning environment in which teachers emphasize personal development and promote relationships of mutual respect among the students (Tomlinson et al., 2003).

As reported by (Fuchs et al., 2010), "differentiated instruction in the general classroom is recognized both as crucial as well as difficult to achieve". For a number of schools, encouraging the application of new teaching practices with emphasis on differentiated instruction constitutes a significant procedure of long-term learning organization, which requires the support on the part of the school leadership (Jarvis et al., 2016; Tomlinson et al., 2008). This changing procedure at this point is likely to be more effective when the application of the change is connected to a wider aim for the improvement of the teaching results (Harris, 2013). Analyzing the manners through which the teachers can comprehend the concept of differentiated instruction in relation to the traditional teaching practice and the way they are involved in chances for professional development is considered to be a vital need and can contribute to the incorporation of innovative teaching methods and changes within the classroom.

2. STEAM and Computational Thinking

Computational science involves the fundamental principles (as the theory of computation), incorporates educational techniques and teaching methods in order to solve problems and promote knowledge (e.g., abstract thought and justification). It also promotes a different way of thinking called computational thinking. The basic principles of this science are related to the methodology and design of theoretical analysis and experimentation, i.e., are based on STEM education (Science, Technology, Engineering and Mathematics). They maintain a cooperative relation with STEM since they fuelat the same timethe cognitive fields of STEM with cognitive content. The field of Art was added to the original STEM turning it into STEAM (Science, Technology, Engineering, Art and Mathematics). Thus, Arts are also included in the promotion of innovation, critical thinking, design and creative solutions.

2.1 Learning and Innovation

In order to be able to create the schools of the future using new teaching methods, innovative developments and exploitation of technology, we must rely on the sciences of learning. Learning sciences indicate how to design environments that teach deep knowledge and adaptable technical know-how that is required in an innovative era. These reports started with the "How People Learn" of the Research Council of the USA (Bransford et al., 2000). Since the first publication of this manual in 2006, OSED has published numerous significant reviews of this research including the innovative learning environments (2013) and the nature of learning: a. use of the research for the inspired practice (2010) and innovation for learning b. learning through innovation (2008). Societies that are able to restructure their schools in the domain of learning sciences effectively will be leading the 21st century (OSED, 2000, 2004, 2008, 2010, 2013). The issues that learning sciences face have been recognized as crucial in all 28 countries under study by the ISTE (Kozma, 2003). These countries' leaders agree that the global economy has changed and is now based on innovation and knowledge. They also claim that education must change in order to be able to successfully support this transition (Plageras, 2018). Therefore, an issue that arises is the delineation of an ever-becoming specific vision for the future of learning. The STEAM approach combines innovation with teaching and offers the students the possibility to construct and apply new ideas and practices as well as deal with the resolution of problems even in areas outside the field of applied sciences such as the subject of History (Plageras et al., 2021). In parallel, we aim at the formation of a creative, original, both different and impressive learning environment, which will offer the students an exceptional learning experience in relation to the conventional learning classroom environment.

2.2 Problem-solving Learning

Problem-solving Learning (PBL) developed in the 1950s to react to the criticism that the conventional teaching method failed to prepare Medical students to be able to solve problems in clinical environments (Hung et al., 2008). PBL is a non-conventional, active, inductive method centered around students and focuses on solving the real problem (Ehrlich, 1998). The problem is a process created by the need to design, build, repair in order to improve something (Burgess, 2004). PBL aims to promote

and encourage active learning, students' development of interpersonal and cooperative skills, open research skills, real-life problem solving use cases and critical thinking (Barrows, 1998; Hmelo-Silver, 2004; Savin-Baden, 2000; Springer et al., 1999). Hmelo-Silver claimed that PBL allows students to set up an extended and flexible knowledge database which goes beyond real knowledge and offers them the possibility to retrieve and apply this amount of information in various situations. Hence, PBL helps students to proceed and move beyond the spiritual understanding of knowledge so that they learn to apply it in the needs of real life. Furthermore, given that knowledge lies within that framework which requires the use of problem-solving skills, teachers consider that the unification of knowledge better prepares the students for their future choices.

In addition, one of the challenges teachers face while applying the problem-solving learning is the students' resistance and their reaction during the transition from the traditional curriculum to PBL curriculum (Hungetal, 2008). Previous research has shown that if there is not appropriately designed teaching approach, students feel frustrated by the open nature of the learning environments based on problem- solving (Yadav, 2006). Research also shows that problematic learning also causes concern and fear among students as the necessary information is not directly available as it is in traditional lecturing. Nevertheless, it has been proposed that the level of easiness on the part of the students improve with the lapse of time and that a period of six months be required in order for them to adapt to the new PBL method (Schultz-Ross & Kline, 1999).

2.3 Flipped Classroom and the Way It Combines with Teaching

Flipped learning within the classroom has become a popular pedagogical method that many educational institutions all around the world use. The main idea behind the flipped approach is that it transfers the teacher's lectures outside the classroom time via internet videos in order to have more available time in the classroom for further learning through activities based on problem-solving. The use of flipped classroom has been extensively studied upon especially within the higher levels of education. Through previous research (e.g., Bernard, 2015; Betihavas et al., 2016; Bishop & Verleger, 2013; Chua & Lateef, 2014; Giannakos et al., 2014; O' Flaherty & Phillips, 2015; Presti, 2016; Seery, 2015; Zainuddin & Halili, 2016; Zuber, 2016) we came to the understanding that flipped classroom approach gives the teachers the opportunity to dedicate more time in the classroom and to the students' skills such as team and individual student work. The students' beliefs and their dedication to the flipping of the classroom are overall positive and through the application of this teaching approach certain indirect educational results may arise. An example of those would be the improvement of the students' communicative skills, the formation of more independent students as far as learning is concerned and the change in the students' habits (e.g., reviewing electronic educational material prior to the examination). When the learning results are being compared to the conventional method ones, previous studies indicate that the flipped classroom approach is able to improve the students' performance or in the worst-case scenario, does not reduce their learning capacity. In published research findings concerning flipped classrooms,

very few studies (e.g., Gundlach et al., 2015) reveal and mention that students were a lot better in the conventional classroom than in the flipped one.

The major problems faced in the flipped classroom include the significant work load on the part of the teachers for the production of learning material as well as the student involvement in the learning process outside the classroom. In reality, previous studies reveal that certain students are not familiar with this learning approach and neglect the educational out of the class material. In certain subjects where the model of flipped classroom has been applied, a considerable percentage of students appears to be disappointed with the open approach within the classroom. Previous studies have presented certain useful data of analytical research in the classroom. Certain studies examine the learning limitations only in higher education (e.g., Bernard, 2015; Chua & Lateef, 2014; O' Flaherty & Phillips, 2015; Seery, 2015). Other studies examined subjected fields usually offered in post-secondary education like nursing, (e.g., Betihavas et al., 2016; Presti, 2016). So far only two articles have been found and reviewed concerning flipped teaching forms in high school students (Bergmann & Sams, 2009; Kong, 2014).

During the current period of writing the present paper, no study of bibliographical review which focuses on the flipped classrooms of K-14 education has been found. Consequently, a systematic review for the examination of the application of flipped classroom in high school students is considered necessary.

Via the present research paper, we contribute to bibliography by examining

a. Students' beliefs concerning the framework of flipped classrooms.
b. Students' attitudes towards flipped lessons.
c. Their knowledge pertaining the software that can support the flipped classroom.

3. Research Aim and Research Questions

The flipped classroom approach has been considered to be an innovation in the high school education since 2012 (Horn, 2013). The aim of the present research is to render the use of flipped classroom and the value of the activities within the classroom, the effects of the flipped classroom on the high school students' achievements and their attitude towards this new approach, understandable. Additionally, the challenges of the use of flipped classroom in high school education have been detected. Along with the views of teachers and students and the existing bibliography, the primary goal of this research is to suggest a flipped classroom model and a set of instructions that could help face these challenges.

Examining the above studies, we end up forming the following questions:

1) What is the high school students' attitude towards the flipped classroom?
2) What are the major challenges coming from the use of flipped classroom approach in high school education?

The flipped classroom can be described as a real fact occurring in the conventional classroom and is now taking place out of it (Large et al., 2000). Nevertheless, the organization of the activities, the

teaching and learning process cannot represent the practice of this educational approach. Bishop and Verlegerventure to formulate a definition of the approach in the classroom. As they define, the analytical approach of the classroom is a technologically supported pedagogy which is composed of two components:

1) The direct immediate individualized teaching through the computer, outside the classroom through video lectures and

2) The interactive learning activities with the help of the exploitation of the team within the classroom.

More specifically, their definition for the demand of the use of educational videos is rather strict as far as their out-of- the classroom learning is concerned. Adopting their definition (Bishop & Verleger, 2013), we can compare the flipped classroom with other old conventional preparation strategies on the part of the students for their daily tasks. Traditionally, students get prepared for their lessons by studying a book on their own. The type of the classroom and the students' study cannot effectively contribute to the support of the flipped classroom in which the teacher is the main element in the learning process (Jensen et al., 2015). On the contrary, teachers can introduce new knowledge to students using educational videos and process the basic idea using examples before they meet in class. Therefore, more time becomes available to be taken advantage of inside the classroom. It can be spent doing group activities and solving real problems with the help of the teacher, the students' cooperation and the help of the software. Hence, we consider the use of educational material, sound and video (e.g., educational videos, YouTube, screencast, Khan Academy, TED ed, podcast) useful for learning outside the classroom and regular (instead of optional) meetings face to face in the classroom as two of the indispensable elements of the flipped classroom approach.

4. Methodology

For our study, 90 middle class students of the second grade of junior high school in the area of Magnesia participated. The students attended a lesson following the model of the flipped classroom. Due to the problematic situation caused by Covid-19 the students did not attend the lessons daily but alternately. This means that half the students attended the lesson live on the first day and the rest of the students the following day. Based on this schedule, the day when the students were not at school, attended the lectures through videos and the next day they did all the activities in the classroom.

The second-grade high school students were taught the resistance connection through the application of the flipped classroom. The students registered in a free e-class platform which contained the whole material and everyone had access to. Before registering, the students were informed about the way they can use the platform for their education. They were informed about the way they can see the uploaded material, ask questions through e-mail and communicate with their classmates. Thus, the students who come to the classroom would have more time to exploit inside the classroom and realize their activities in virtual labs. They could experiment with the mistake without the danger of destroying the material.

There was constant contact with the research team, the students and the teacher so as to solve all sorts of the students' questions and follow the lesson without further problems.

4.1 Activities

In the first activity the students tried to create a simple electrical circuit by exploiting the virtual laboratory Tinker Cad.

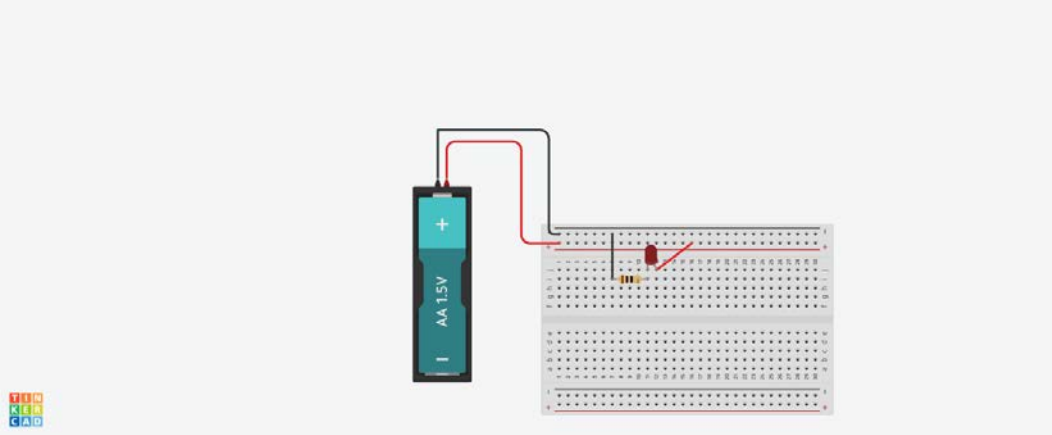

Figure 1. Simple Electrical Circuit

As soon as the project is completed, they performed the same task with the same material in the regular laboratory. The aim of the task is to observe the conditions of the operation of the simple electrical circuit and by changing the value of the resistance each time, to observe the LED brightness. In this way, the students will be able to control the operation of the simple electrical circuit and how the modification in the resistance affects the intensity of the electrical current in the circuit.

In the second activity the students assembled the following circuit.

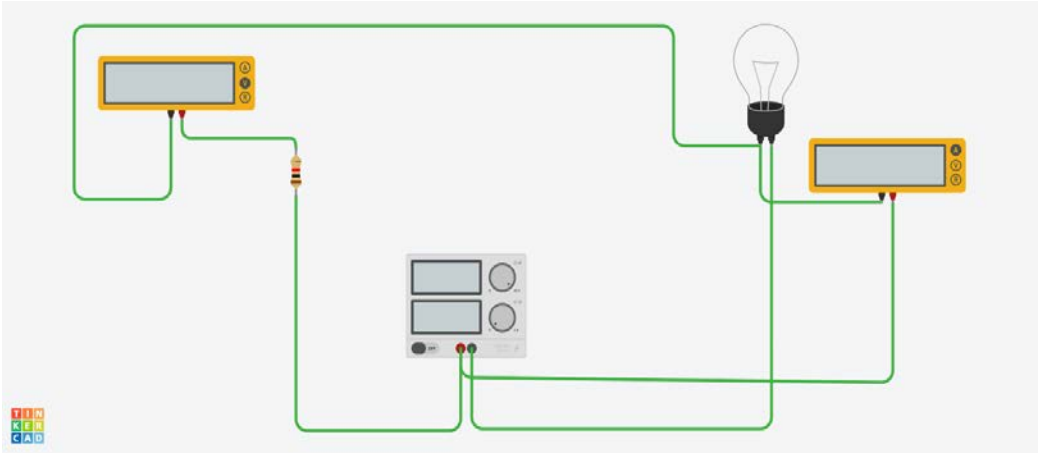

Figure 2. Electrical Measurements in a Circuit

In the same way the students assemble the above circuit first in real life and then in the virtual laboratory. The aim is to record the various values of the tension and how the tension of the electrical current in the circuit is affected and whether this fact affects the brightness of the bulb. Thus, they will perceive the proportion of the values of tension and electrical current.

Lastly, in the third activity the students have been asked to place a resistance in the circuit in picture 2 before the light bulb and by altering its value, to observe what is happening with the brightness of the bulb and record it. In that way they will understand the role of the resistance in an electrical circuit and comprehend what happens inside our house when multiple electrical appliances operate simultaneously. They will also realize the concept of safety in electrical circuit. The duration of the lesson was 3 hours in the classroom and one hour of study at home.

5. Results

The students, when asked by the researchers about their knowledge relating to the flipped classroom prior to the intervention, answered in their majority that they had no knowledge about it whatsoever. They had no particular contact with educational software and no image at all of its use.

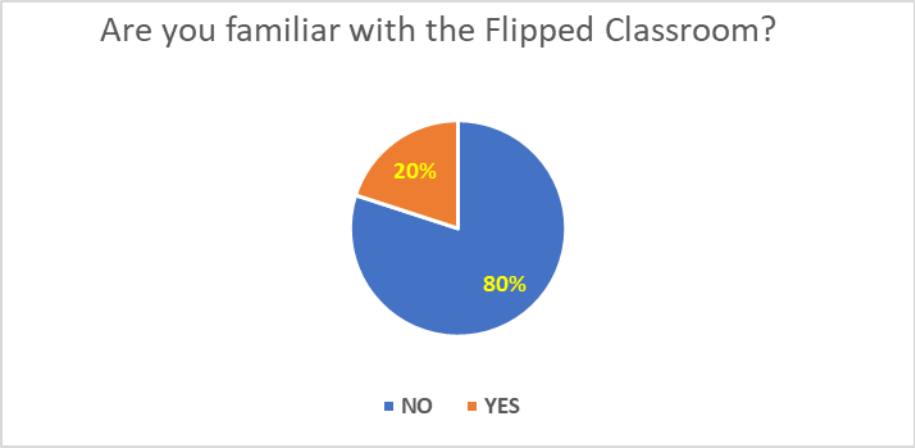

Figure 3. Graph 1

The change in the students' attitude before the intervention, immediately afterwards and after a month is shown in the diagram below.

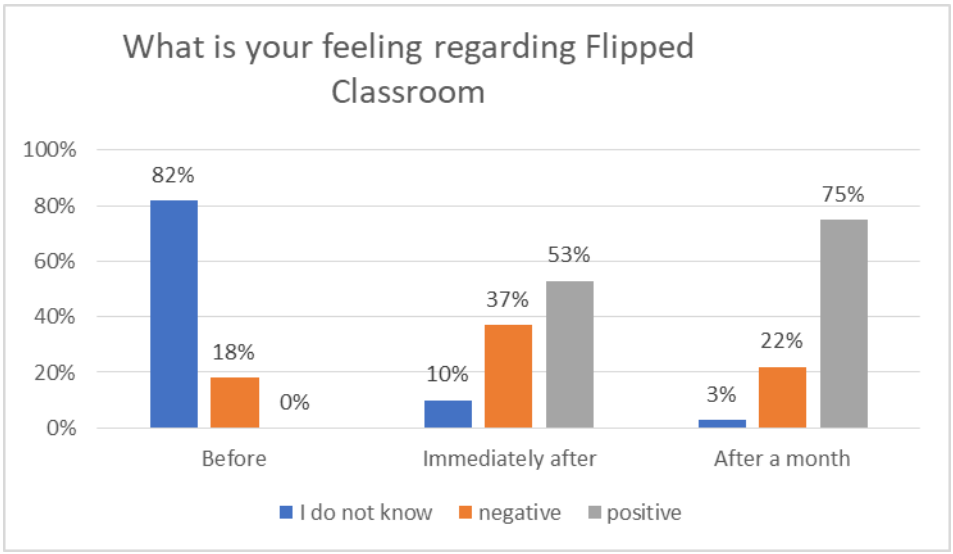

Figure 4. Attitudes towards the Use of Flipped Classroom

As we see in the above diagram of Figure 4, the change in the feeling of the students about teaching in the flipped classroom demonstrates significant modification and it is particularly important that the trend was increasingly positive even after a month after the intervention, a fact that shows incorporation in the students' perception to a great extent.

Lastly, as far as the question "which method would you prefer to use in your classroom" is concerned, the students' answers are shown below in the following diagram.

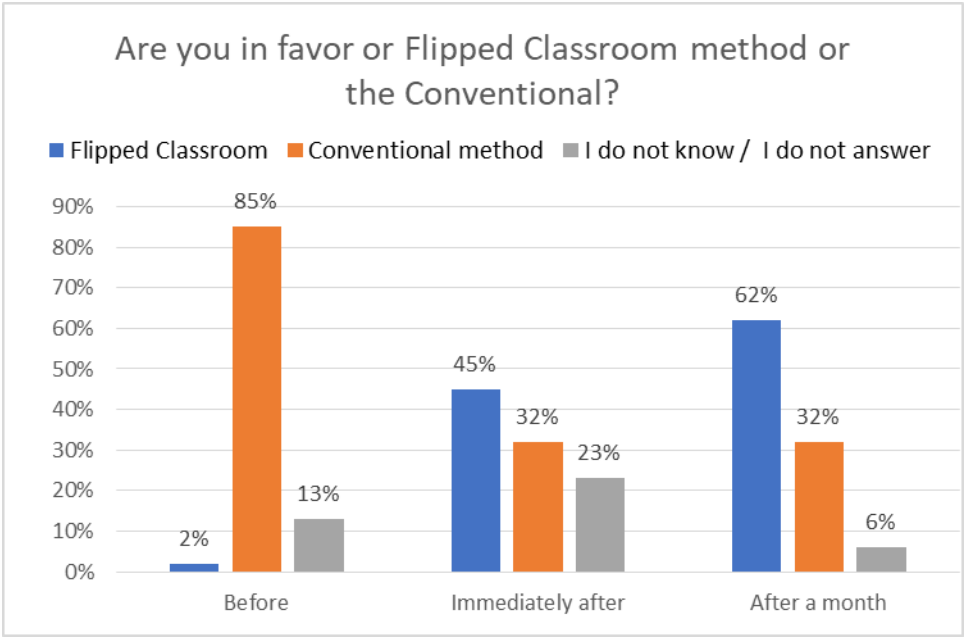

Figure 5. Attitudes towards the Use of Flipped Classroom vs Conventional

An important finding in this question is that the students who chose the conventional method after the intervention have remained stable in their opinion even after a month. On the contrary, those who have selected the flipped classroom method presented a rising trend in the final measurement, a fact that shows an acceptance of the method in the student community as a basic teaching method.

6. Discussion

The present research claims that the high school students who have exploited differentiated forms of teaching in the classroom will have better results in the comprehension of the curriculum or at least will carry out their tasks equally well as in the conventional teaching way. This finding was similar to the conclusion of previous research about flipped classroom in relation to higher education (e.g., Betihavas et al., 2016; O' Flaherty & Phillips, 2015). Also, in some cognitive fields in higher education such as the chemistry field in Seery (2015) research total acceptance of the flipped classroom is stated.

The present research does not end up with total acceptance for the specific intervention. Even though their attitude changed and was generally positive, several students claimed that they would prefer the conventional teaching approach because of their weakness to pose questions during the video lectures and had difficulty getting accustomed to this approach (Schultz et al., 2014). De Santis et al. also observed that their students reacted generally negatively to the change of the teaching method for the same reasons. In the meantime, the educational videos produced by the members of the research team did not show the teacher in the classroom, a fact that made acceptance of the method even more difficult. The satisfaction on the part of the students in the flipped classroom was eventually higher than that of the conventional method.

As far as the challenges of the flipped classroom are concerned, most of the problems which have arisen have been observed within the framework of the students' education. As for the students' challenges, some of them were not open to the curriculum structure in the flipped classroom approach as in the research by (Giannakos et al., 2014). Moreover, the students had a negative feeling as far as the preparation time range outside the classroom is concerned, as in the research by (Betihavas et al., 2016). It is necessary for the teachers to carefully design the educational material for the lecture exploiting the video, as students may get carried away and misunderstand while attending the class online (Schultz et al., 2014; Snyder et al., 2014). In addition, the students are likely to have questions during the video lectures (Bhagat et al., 2016; Schultz et al., 2014). As far as the group activities within the classroom are concerned, the students seem to need more guidance for the team procedure in order to work more productively as (Grypp & Luebeck, 2015) report. In the present research paper, there has not been a reduction in the participation of the students as reported by Giannakos et al. (2014), since it has been completed in one lesson. Nevertheless, regular attendance may have to do with the strict schedule followed by the high schools and not with the use of the flipped classroom approach.

The challenges faced in the classrooms of the junior high school units are similar to the ones in higher education levels. Firstly, flipping the classroom requires more personal initial work on the part of the

teacher specially as far as the production of the educational material is concerned (Betihavas et al., 2016; Giannakos et al., 2014; O' Flaherty & Phillips, 2015). Second, the teachers must be adequately qualified in order to use the flipped classroom approach and exploit to the fullest the potential of this approach (Zuber, 2016). Compared to higher education, more business challenges have been defined within the junior high school framework as many students have limited access to the Internet (Betihavas et al., 2016). In the meantime, teachers in secondary education may experience difficulties in monitoring the learning process outside the classroom. They may also experience technical issues and demand support from the schools during their flipped method process.

In order for everything to be practical in most learning environments within the junior high school framework, we presuppose the following: We have only basic information technology resources (video production, internet access). Therefore, the flipped classroom model will not be based on special operations of certain independent systems (e.g., La & Hwang, 2016). The central teaching strategy in out of the classroom learning constitutes a direct order (Bishop & Verleger, 2013; Kirvan et al., 2015) which focuses on the levels of knowledge of acquisition and comprehension (Lai & Hwang, 2016). Students learn the lessons by following educational videos. The teachers can provide content notes in order to guide the students (Desantis et al., 2015) and make sure that students have been appropriately prepared for the class meetings (Clark, 2015).

Towards the end of out-of-the-classroom learning, teachers can provide online exercises for the evaluation of learning (Wang, 2016). Through controlling the learning performances of the students on online lessons, teachers can have a discussion concerning misunderstandings or possible questions in relation to the error high rate inside the classroom (Lai & Hwang, 2016). In order to support the out-of-the-classroom learning process, teachers can provide students with a communication platform so as to submit their questions (guideline 5). As far as the educational component in the classroom is concerned, teachers can firstly have a brief overview of the video lecture in order to jog the students' memory and clarify potential misunderstandings (e.g., De Santis et al., 2015; Grypp & Luebeck, 2015; Lai & Hwang, 2016). The remaining time can be spent on group activities (Bishop & Verleger, 2013) which focus on the application of knowledge acquired through the video lectures (Lai & Hwang, 2016) and real problem solving (Tsai et al., 2015).

7. Conclusions

The findings of the study demonstrated that differentiated teaching is more beneficial for the improvement of the academic results. It has been defined that the use of differentiated teaching has a positive impact on students after examining the collected data. The application of differentiated teaching has a positive effect on the students' achievements. The students taught through differentiated teaching performed better than those through conventional teaching approach (Plageras et al., 2020). Differentiated teaching using the flipped classroom is a constantly promising approach for the support of various needs of all students as it affects positively their achievements. The conclusions of this study

encourage the use of differentiated teaching as it constitutes a significant benefit for the students who may try in the classroom given the fact that not only the strengths but also the differences of the students are recognized. The increasing diversity inside the classroom is also a given. Differentiated teaching inside the classroom is an effective teaching method of applied sciences since it offers students practical learning and more communication opportunities with their classmates in comparison with the conventional teaching approach.

Based on the findings and conclusions drawn in this study, the adoption of differentiated teaching for the subjects of Technology, Electrology etc. is recommended. The evaluation of the teaching aims of the lessons and the massive restructuring of the analytical curricula will have to be done in order for the use of the differentiated teaching approach to be incorporated in various cognitive fields. This fact is due to the positive influence exerted for the achievement of the aims when the differentiated teaching method was used. Writers of the analytical curricula should include the differentiated teaching approach in the teaching of applied sciences. During the teachers' instruction and education in university institutions of the relative specializations, certain programs using differentiated teaching approaches should be developed and provided for.

Educational and informative meetings should be realized and motives for the professional evolution of the teachers applying differentiated teaching approaches should be given which at the same time require coordinated cooperation of both teachers and headmasters of the schools (Plageras et al., 2020). For instance, what can be used in the classroom is group discussion (Bhagat et al., 2016; Lai & Hwang, 2016) and cooperative homework (Clark, 2015). Nevertheless, teachers can still provide practical exercises for the students' individual tasks (Clark, 2015). Solving problems is equally important for effective learning. In certain cases, teachers can think about the possibility to introduce a brief lecture in order to present the content of the lessons (Tsai et al., 2015) and expand the students' knowledge (Lai & Hwang, 2016). For instance, the researchers (Schultz et al., 2014) suggested that the difficult concepts be presented in class and not through video. It may be more appropriate for teachers to present more complicated concepts inside the classroom. In that way, teachers can have an immediate contact with the way students acquire knowledge better and achieve greater results through developing the difficult parts according to the students' questions.

Finally, the teachers can organize the classroom (Huang & Hong, 2016) for example, ask the students to gather in groups and overview what they have acquired (De Santis et al., 2015). Teachers can also have a brief out-of-class review for the next lesson (Huang & Hong, 2016) in order to motivate the students. However, we suggest that the flipped classroom model be incorporated following specific instructions so as to prevent potential challenges from taking place. For example, we propose that the use of video not exceed five minutes. We also recommend that the completion of the out of class tasks be limited to twenty minutes maximum. These strategies can prevent the distraction of the students' attention from the video lecture and set them free for the preparation of the classroom activities (Lo & Hew, 2017).

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