education sciences

MDPI

Article

The Study of Flipped-Classroom for Pre-Service Science Teachers

Jin Su Jeong [1,2,*], Florentina Cañada-Cañada [2] and David González-Gómez [2]

[1] Department of Mechanical Engineering, Chemistry and Industrial Design, School of Engineering and Industrial Design, Polytechnic University of Madrid, 28012 Madrid, Spain
[2] Department of Didactics of Experimental Sciences and Mathematics, University of Extremadura, 10003 Cáceres, Spain; flori@unex.es (F.C.-C.); dggomez@unex.es (D.G.-G.)
* Correspondence: jinsu.jeong@upm.es; Tel.: +34-913-365-620

Received: 16 September 2018; Accepted: 30 September 2018; Published: 2 October 2018

check for updates

Abstract: The relatively new methodology, flipped-classroom, is one of blended learning instruction methodologies in which the traditional-classroom is inverted. This methodology asserts that students can participate and engage more successfully in their class and can attain better learning when their classroom is flipped. This work presents a two-year study to measure the effects of the flipped-classroom model on the performance, perceptions, and emotions for teacher training students in science education. Particularly, this research was carried out during two courses, 2014/2015 and 2015/2016, in a general science subject. With a post-task questionnaire, we obtained the information to assess their performance, perceptions, and emotions, toward the class. The results confirmed that a statistically significant difference was found on all assessments with the flipped-classroom students, performing higher on average, showing favorable perceptions, and demonstrating positive emotions about the flipped-classroom model. Thus, the students were ready to take more courses pursuing a flipped-classroom model. The results achieved in this study show a promising inclination about the performance, perceptions, and emotions of students toward the flipped-classroom methodology, and will provide an entirely a new impetus for this relatively new instruction methodology.

Keywords: science education; inverse methodology; pre-service teacher students; performance; perception; emotion; new tendency

---

1. Introduction

The flipped-classroom intends to engage students more effectively by inverting what traditionally has been followed in a classroom. In this new setting, content is delivered outside of the classroom and employs in-class time on more student-centered activities. The flipped-classroom model, introduced by high-school chemistry teachers Jonathan Bergmann and Aaron Sams, is a relatively new instruction methodology [1,2]. This relatively new instruction methodology has its foundations in constructivism and the social learning theory [3–5]. For example, in a regular flipped-classroom, lectures and classes are provided to the home by the way of video-lecture materials along with written supplies and on-line quizzes and tasks [2,6]. Therefore, classroom time is more focused on student-centered learning activities, such as collaborative exercises, making more interactive courses, and allowing to address specific questions as to deliver just-in-time lectures [7,8]. Also, a flipped-classroom model can be considered as a mixture for both traditional and online education systems by utilizing in- and out-of-class time, completing more effective learning chances and perspectives [2,9]. Particularly, the main characters of this flipped-classroom instruction methodology are the students, who have more responsibility in the process of learning [1,10], rather than for instructors. Accordingly, when a flipped-classroom model is respected, their performance, perceptions toward the course and subject, and students' emotions developed during the learning process must be appraised in order to completely set this relatively new instruction methodology.

The student-centered instruction design in education makes it more important to evaluate the performance and achievement of students on the pedagogical methodology [8,11]. In the instance of the flipped-classroom model, university studies' evaluation and assessment are still under reported and informed, especially in science, technology, engineering, and mathematics (STEM), and numerous preliminary courses [12]. Particularly, Love et al. [12] indicate that the flipped-classroom showed that the success of students' performance meaningfully improved in introductory courses in STEM, which attained better outcomes and increased pleasure. Moreover, the final exam results of students who followed the flipped-classroom model were improved and represented students' conceptual and theoretical understanding of the subjects and contents. In an engineering senior class, similar findings were performed and reported [13,14]. In addition, this research denotes that more teaching materials and resources were used when a flipped-classroom was followed. Comparable results were explained in a mathematics course [15,16] where the flipped-classroom model improved the grades of students. Also, this work suggests that the flipped-classroom model demonstrated its higher accuracy, especially on moderate complexity items.

In the context of students' perception, different researchers agreed that students have a positive perception towards the flipped-classroom model in distinctive educational levels and situations. Specifically, a 2015 study with 142 students in two different classes shows that students favored the flipped-classroom model [17–19]. Butt and Smith [20,21] indicate that students in STEM courses not only preferred using the flipped-classroom methodology, but also a majority of students specified that the teaching instruments used in the flipped-classroom model were valuable as a learning tool [20,21]. In the same context, Roach [18] also underlines that the capability to watch or re-watch the flipped materials permitted students to overcome difficulties and complexity, which is related with more multifaceted notions and concepts. Moreover, the nature of the activities achieved in a flipped-classroom model that foster the active participation of students by means of active learning strategies is positively noticed by students as well [22].

In the teaching and learning process, many research has pointed out a close connection between the cognitive and affective dimensions [23,24]. Emotions perform as a social glue that can interrelate and interconnect individual and collective benefits and actions in students' learning processes [25]. Besides, the constructivism theory points to emotions as significant extents in teaching and learning environments [26]. Their conceptual and theoretical change can be limited when instructors ignore the emotional facets related with the learning process [27]. Specifically, in a STEM course, emotions perform as a key axis to accomplish substantial learning [28]. In reality, positive emotional conditions encourage science learning and expand students' commitment, like active learners, while negative emotions hinder the learning capability [29,30]. According to various research, the emotional rejection of students is one of the main causes of failure of courses, especially in a STEM setting, because many students feel negative emotions, such as fear, nervousness or concern [30,31]. Therefore, a suitable instruction methodology, flipped-classroom model, and teaching strategies can increase positive emotions and/or reduce negative emotions, which could have a positive impact on teaching and learning process.

2. Objective and Research Questions

The main objective of this research was to measure and assess the students' performance, perceptions, and emotions when a flipped-classroom model was followed as an instruction methodology for pre-service science teachers. Thus, the research questions (RQ) that this study aims to answer are:

- RQ1: How does the flipped-classroom methodology influence learning outcomes in a science course?

- RQ2: Do students have a positive perception toward a flipped classroom methodology when used in a science course?
- RQ3: How does the flipped-classroom methodology influence the students' emotions when a flipped-classroom methodology is followed in a science class? If so, is this influence positive or negative?

3. Materials and Methods

This research was carried out in a general science course for a sophomore class of the Primary Education bachelor degree of the Teaching Training School of the University of Extremadura, Spain during two courses: 2014/2015 and 2015/2016. A total of 153 students participated in the study. The particular subject syllabus for this study contains the matter and the energy of general science topic, and it was taught in the second semester 4 hours/week and was compulsory for all students.

3.1. Flipped-CClassroom Instructinal Design

At the beginning of the semester, the flipped-classroom paradigm was presented to the students along with the class flowchart, which contained all the important dates and class activities programmed. The course structure consisted of theoretical and laboratory contents (3 sessions of 50 min weekly and 1 session of 50 min weekly per groups, respectively). Specifically, it had five sections according to the contents and learning difficulties. Here, all students used a Moodle virtual interface of the university for delivering the flipped-classroom contents.

As shown in Figure 1, Doceri and ScreenFlow software tools were utilized for elaborating asynchronous video lectures. Particularly, Doceri software was a very useful alternative tool, which can deliver science classes to multiple distance campuses with synchronous and asynchronous online instruction [32]. The instructors encouraged the students watching the video lectures before the class based on the class schedule. Besides, eduCanon and PlayPosit, which are online learning environments, were utilized to make the video-lecture materials more appealing and to create interactive lessons for the students. Here, quiz questionnaires were included in the video lectures, which could provide additional emphasis and information in difficult parts of the content and provide feedback to the instructors before the class, increasing the students' engagement and delivering just-in-time lectures required.

Taking the lecture out of the classroom, the students participated more actively in the in-class time, rather than being passively note-taking and listening to the lectures. With this instruction structure, the students consumed in-class time working on various problem sets such as numerical and non-numerical tasks developed by the instructors, together with lab demonstrations. Furthermore, they worked on published materials, small group discussion and case studies, where the instructors gave to the students a real-world problematic and tricky conditions related with the class content reviewed in the video lessons. The instructor's role in these sessions was to observe situations, address concerns, and distribute clarifications when they were required.

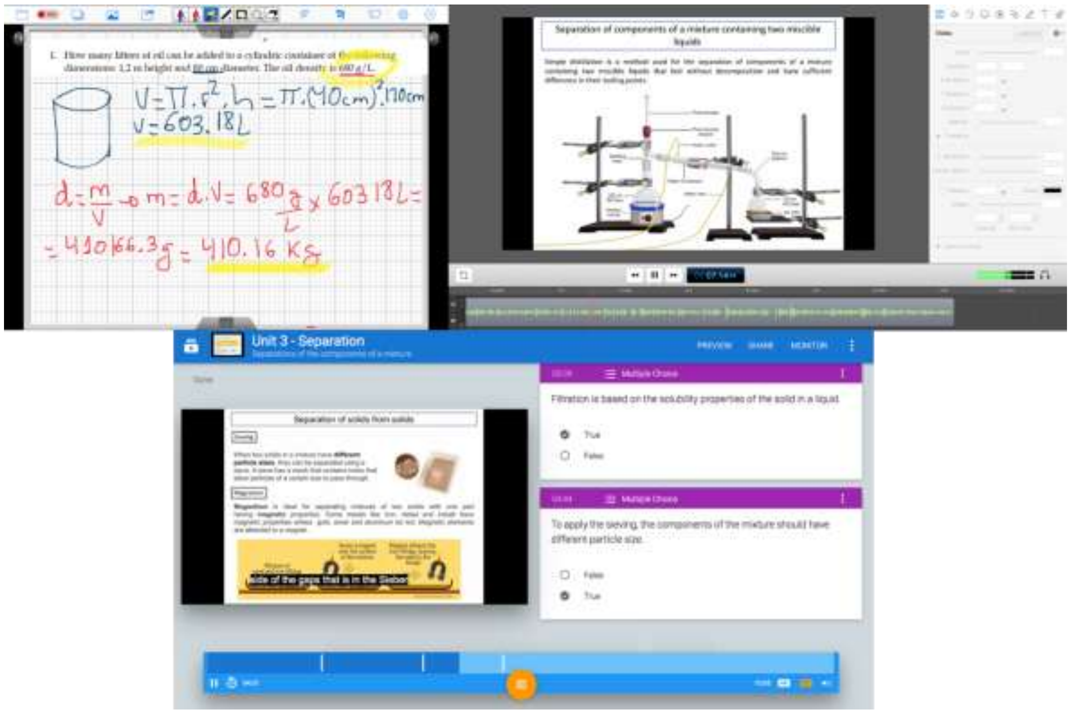

Figure 1. Various software tools used to make flipped-classroom materials of the study (Doceri, ScreenFlow, and PlayPosit as the position of left, right and bottom).

3.2. Statistical Analysis and Survey Questionnaire

For this research, the students' performance, perceptions, and emotions were assessed when a flipped-classroom model was followed as an instruction methodology for pre-service teacher students in science education. Performance data was based on the grades obtained from the different activities carried out during the course, precisely from in-class activities, laboratory activities, and final exam. Thus, the performance measurement of the students for the flipped-classroom model indicates their average grades for the subject. Besides, in order to measure the flipped-classroom model or its success, the students' percentage showing the successful completion of the subject in the course end was assessed. Regarding the students' perceptions and emotions, a post-task questionnaire survey was conducted to measure the perception and emotion of the students at the end of the course. The questionnaire based on previously published research [18,33] and validated for this study consisted of three sections: socio-demographic information, perception, and emotion questions. Regarding the students' perception measurement, a five-point Likert-type questionnaire was applied to the questionnaire adapted from Roach [18]. Here, participants need to give their opinion form, strongly disagreed (SD), disagreed (D), neutral (N), agreed (A), and strongly agreed (SA,) to the sample study. In the case of the students' emotion measurement, a prose-designed questionnaire based on previous validated studies were applied. In this study, we considered two emotion groups: positive and negative emotions. Particularly, positive emotions contained fun, confidence, enthusiasm, and tranquility and the negative emotions included nervousness, concern, boredom, and fear. Here, participants expressed their opinion as the frequency of happening by a 0 to 10 scale, where 0 meant the lowest frequency and 10 meant the highest frequency of occurrence for each emotion. In order to get a better description of the flipped-classroom model in the students' emotions, the gender and educational background were considered in the inter-course comparative studies.

When a comparison of two different courses, 2014/15 and 2015/16, was conducted, a two-sample t-test of independent unequal sample from normal distributions was carried out in order to find the existence of significant differences. Also, for the effective degrees of freedom, the Satterthwaite's approximation was utilized. All calculations and computations were completed with different open-code toolboxes written for MATLAB and available on the MATLAB official website.

4. Results

4.1. Sample Description

Toward a flipped-classroom model measurement on the performance, perception, and emotion, this work was performed in a general science course a total 153 students (65 and 88 students, respectively) participated in the study with the specific demographic information as shown in Table 1. Sixty-one percent were males and 39% females for 2014/2015, and 65% were male and 35% were female for 2015/2016, the average age of the participants was 21years old. The grade point average (GPA in a 0 to 10 scale) at the beginning of the second semester was 6.81 for 2014/2015 and 6.95 for 2015/2016, slightly 0.14 points higher in 2015/2016 course. Based on the educational background, the participants described below in the table that most students for both academic terms were from social sciences (71% and 63%, respectively).

Table 1. Demographic information of a total 153 students for the study proposed.

Items	2014/2015	2015/2016
Male	61%	65%
Female	39%	35%
Age	21	21
GPA	6.81	6.95
Social Sciences	71%	63%
Science	20%	18%
Arts	0%	5%
Technology	1%	3%
Others	8%	11%

4.2. Performance Analysis and Evlauation

According to the university statistical data provided and specified, students always have had some difficulties to finish satisfactorily the subject proposed for this study. Most of the basic concepts required to understand the subject and relevant scientific contents were already forgotten by students and/or they have never been learnt. In detail, students took 2.5 years to pass this subject on average, and thus, only a small ratio of students required up to four years to finish it. The passing rate was checked in order to measure the flipped-classroom model or its success. For 2014/15 course, the passing rate was 56.6% and for 2015/16 course was 57.2% showing the increase tendency from the previous years (before 2014/15 course). From these results, the passing rate for the flipped-classroom model was over the passing rate in previous years. To complete the students' performance, the results from the students in the different type of exercises, tasks and exams of the course are summarized as shown in the Figure 2. For a comparison purpose of these two courses, this figure also includes the students' performance during course 2013/14 where the flipped-classroom model was not applied. The results of assessment for the various and distinctive type of tasks were created by the means of a 0 to 10 points scale. We also can detect similar results that all different types of activities, exercises and exams in the flipped-classroom model were over the passing rate in previous years aforementioned.

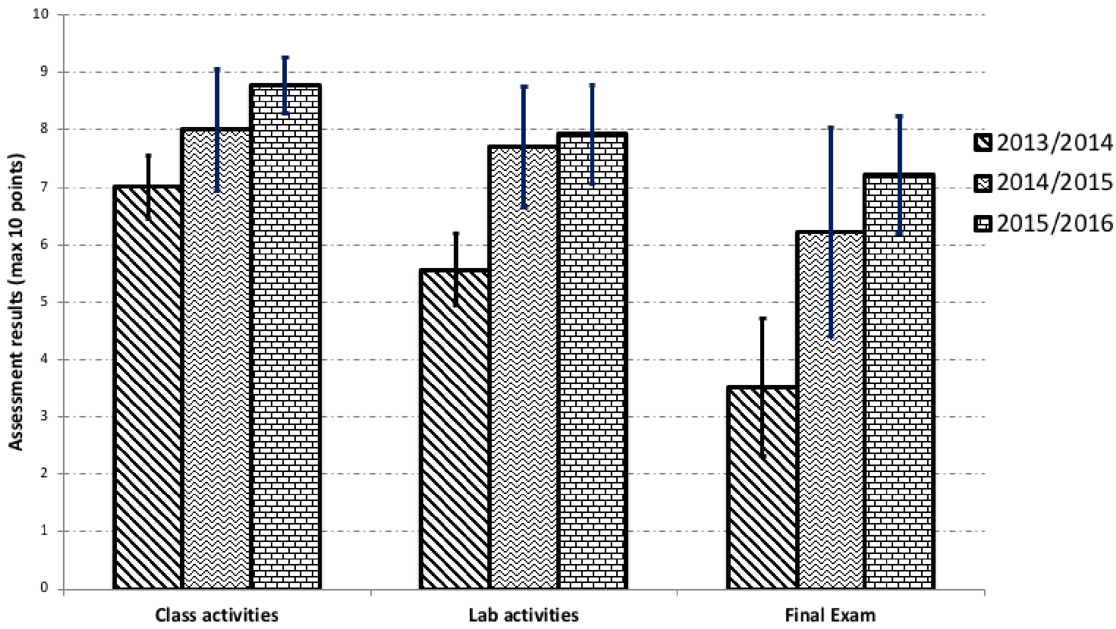

Figure 2. Performance analysis of students' achievements during 2014/15 and 2015/2016 courses where a flipped-classroom model was followed and 2013/14 where a traditional teaching model was followed.

According to the data shown in Figure 2, significant differences at the 95% significance level ($p < 0.05$) were observed after comparing the students' performance when a flipped-classroom was followed (2014/15 and 2015/16 courses) and when it was not followed (2013/14 course). No significant differences at the 95% significance level ($p < 0.05$) were observed between students enrolled in the flipped-course in the two different years (2014/15 and 2015/16 courses).

4.3. Perception Analysis and Evlauation

The results collecting the opinions from the students showed that there was a general positive perception about the flipped-classroom model employed (see Figure 3). Nearly 97% students considered that *watching video-lessons before attending class was very meaningful in order to accomplish the proposed learning goals* (Q1). *For video-lesson materials were correctly designed, well-structured, and clearly-defined* (Q2), mostly students agreed or strongly agree with the statement. For Q3, *in your opinion, it was not necessary to provide video-lessons in order to achieve laboratory and class learning objectives*, only 3% students strongly agreed, and 11% of them agreed with the statement. Here, we found out an interesting fact that video-lessons were very instructive and useful for realizing the learning goals. Also, the students who did not watch video-lectures at all before asynchronous and synchronous class felt considerably more behind than the students who did. So, during the class, they could not follow when they were asked to contribute to hands-on projects and discussions. When the students were surveyed how to complete multiple-choice on-line quizzes after watching the video-lessons delivered and to achieve more efficiently the laboratory class learning objectives (Q4), they agreed or strongly agreed that the quizzes provided together with the multimedia materials allowed them to accomplish the learning goals. In their opinion, these research questionnaires denoted to emphasize the related contents and notions and to raise doubts to be resolved in the class. Almost 90% students could point out the most complicated contents and notions before the class, and therefore, could focus to overcome them after finishing the on-line quizzes postulated with the video-lesson materials (Q5). Besides, the instructors can blend the teaching to overcome the difficulties of the students and to use efficiently more the class time as the result of the questionnaires just-in-time. Ninety-five percent of students solved their doubts for the lecture and laboratory sessions (Q6). Particularly, Q7 and Q8 are for checking the general perception of students about how useful were the classes, theoretical and laboratory class, for their professional training as a future primary teacher and whether the course satisfied their professional training requirements as a future teacher (Q8), regardless of the pedagogical model utilized. All of the students agreed (49%) or strongly agreed (51%) with the articulated statement for Q7, although 8% of students found that the course did not fulfill their professional requirements for Q8.

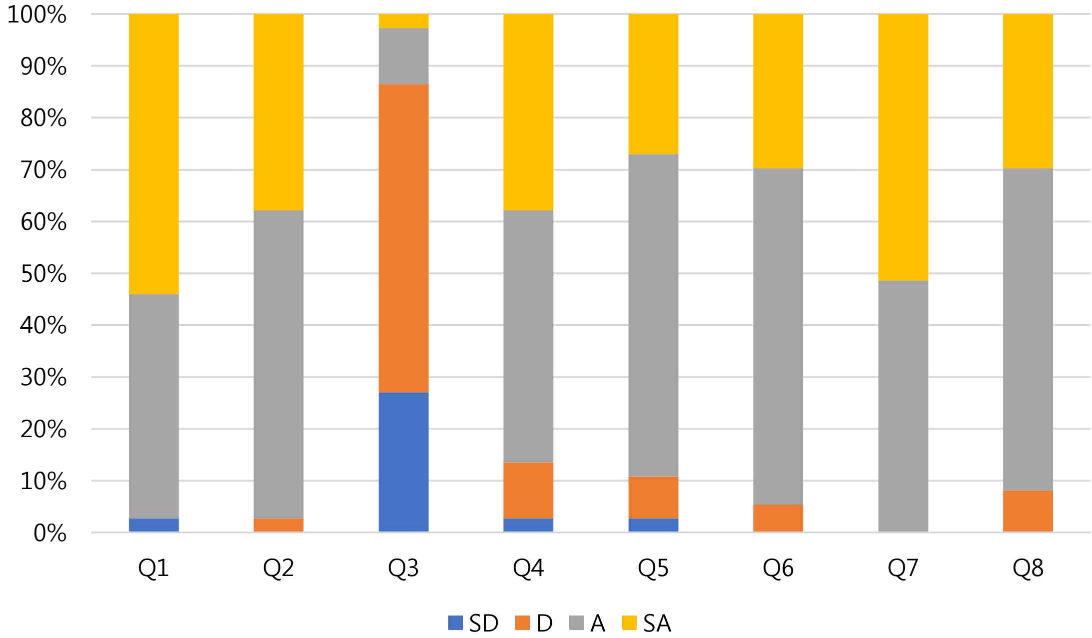

Figure 3. Perception analysis of five-point Likert-type test of 8 questions as percentage of students' answers (Data from 2014/15 and 2015/16 courses as mean values).

4.4. Emotion Analysis and Evlauation

Figure 4 summarizes 8 emotions' mean values provided and assessed by all students based on a 0 to 10 scale. Generally, the overall scores were very high in positive emotions. Amongst these 4 emotions, the students expressed the highest score to the emotion of fun and enthusiasm (over 7 points) and confidence acquired the lowest score amongst the positive emotions. In the context of the negative 4 emotions, the lower scores were corresponding to them. Boredom was recorded with the lowest value of 2.52 and concern was gotten as the highest value of 4.99 amongst the negative emotions. It was related with the emotion scores given for the negative emotions, which were more distributed, with significant higher standard deviation values.

When the students' gender is deliberated, the women's group expressed generally higher values in negative emotions, but both gender variables did not have differences in positive emotions. Particularly, the emotion of confidence, nervousness, and fear was significantly different in both groups at the 95% significance level ($p < 0.05$ in all cases). Regarding the students' educational background, it was also considered to measure the students' emotions evolved in a flipped-classroom model. Here, we sorted into two groups based on their educational background: first, social sciences and arts background is the first group, and a science and technology background is the second group. Results showed that positive emotions achieved higher scores than negative ones regardless of the students' educational background. Particularly, fun, enthusiasm, and tranquility as the positive emotions scored between 6 to 7 and no differences were found out amongst both groups. The first group expressed higher scores in the negative emotions (over 5 points). The second group showed more scores in confidence and lower scores (below 4) in the negative emotions. The both groups indicated the same low scores.

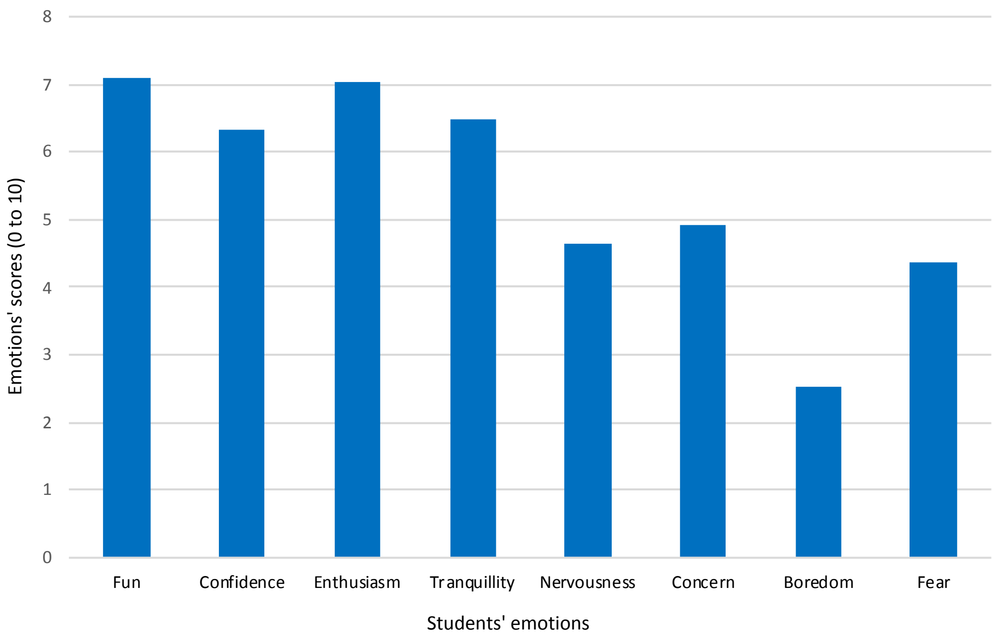

Figure 4. Emotion analysis of 0 to 10 scale test as percentage of students' answers toward 8 different emotions (4 positive and 4 negative emotions). (Data from 2014/15 and 2015/16 courses as mean values).

5. Discussion

According to the measurement of the students' performance (RQ1), it was determined the subject passing rate, final exam grades, and other exercises grade of students at the same year and for the first-time during class and lab sessions when the flipped-classroom model was used as instruction methodology. The results demonstrated that the flipped-classroom model gave better outcomes than previous classes not applying the flipped-classroom model. Particularly, the students' passing rate increased more than 10% in the same year and for the first time enrolled. For the final exam scores, the students' grades were notably higher than the students' grades obtained in previous years. Also, similar variances were also detected in in-class assessments and the lab taken during the course. Previously published research [15,16,34] regarding the students' performance indicated that there is not enough evidence to support assertions of the flipped-classroom model benefits in the students' performance. Christiansen [35] shows similar conclusions described in a more limited study and a much smaller class group. Love et al. [12] describes a study carried out in an algebra course were no significant differences were observed after using the flipped-classroom. Thus, the results obtained in this research show a significant tendency in which the flipped-classroom has a significant effect in performance. Thus, similar results and conclusions are informed in an engineering course [13,14] where students' performance were significantly higher with a flipped-classroom model.

According to the measurement of the students' perception (RQ2), the students had an overall positive opinion about the flipped-classroom model applied for this class. They found the model was useful or very useful, as the video-lesson provided in the flipped-classroom model was helpful, that is, not only for accomplishing the learning objectives, but also for engaging them more successfully with the course contents and notions. It can be defined that the flipped-classroom activities were more student-oriented. Based on the questions distributed, generally, most students agreed or strongly agreed that the flipped-classroom model provided them the probability to work independently. In their own place, the possibility of watching and re-watching the video-lesson materials was of great assistance, particularly for the students to catch up on missed class materials.

According to the measurement of the students' emotions (RQ3), it can be observed that the highest scores were given to the positive emotions, fun, and enthusiasm as the most scored positive emotions.

Amongst the negative emotions, boredom got a lower score. Therefore, the students attended to a flipped-classroom model had a more positive and less negative emotions. Particularly, the women's group provided higher scores to negative emotions. Regarding the students' educational background, a science and technology background postulated lower scores to the negative emotions evaluated in this study, but the positive emotions were in the same order as a social sciences and art background.

6. Conclusions

This research aimed to assess students' performance, perceptions, and emotions when a flipped-classroom setting was followed as an instruction methodology for teacher training students in science education. Particularly, this research was carried out during two courses: 2014/2015 and 2015/2016 in a general science subject previously mentioned. With the post-task questionnaires, we obtained the information and measurement to assess their performance, perceptions, and emotions toward the class.

Considering the research questions established for this work, we can conclude better learning outcomes are achieved when a flipped classroom methodology is applied in a science course. The study conducted during two different courses indicate that this effect is consistent. In addition, when the majority of students were satisfied with the class setting, they agreed to consider that the course was a valuable learning experience in general, and they perceived the flipped materials adequate to achieve the learning goals. Furthermore, the results suggest that a flipped learning method fostered students' participation more effectively than traditional teaching formats. With regard to the emotions assessments, this research reveals that the flipped-classroom methodology had a significant influence on students' emotions toward the science course. Positive emotions were highly scored by the students. Especially, they attended class in a more confident and tranquilly way. The flipped methodology made a great positive impact, in terms of emotions toward the course, when students did not have a science educational background. That is especially relevant since the majority of students that participated in this study did not take sciences in the previous years (middle and high school).

Author Contributions: This work is the result of the collaboration between all authors. All authors have equally contributed, reviewed, and improved the manuscript. All authors have revised and approved the final manuscript.

Funding: This work was financed by Research Project EDU2016-77007-R (AEI/FEDER, UE) of the Ministry of Economy and Competitiveness of Spain.

Acknowledgments: We acknowledge that this research is supported by the Juan de la Cierva-Formación of the Ministry of Economy and Competitiveness of Spain (ref. JDC-2015). The authors are very grateful to the program that made this work possible.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Tucker, B. The Flipped classroom. Online instruction at home frees class for learning. *Educ. Next* **2012**, *12*, 82–83.
2. Munir, M.T.; Baroutian, S.; Young, B.R.; Carter, S. Flipped classroom with cooperative learning as a cornerstone. *Educa. Chem. Eng.* **2018**, *23*, 25–33. [CrossRef]
3. Hill, J.R.; Song, L.; West, R.E. Social learning theory and web-based learning environments: A review of research and discussion of implications. *Am. J. Distance Educ.* **2009**, *23*, 88–103. [CrossRef]
4. Sams, A.; Bergmann, J. Flip your students' learning. *Technol. Rich Learn.* **2013**, *70*, 16–20.
5. González-Gómez, D.; Jeong, J.S.; Gallego Picó, A.; Cañada, F. Influencia de la metodología flipped en las emociones sentidas por estudiantes del Grado de Educación Primaria en clases de ciencias dependiendo del bachillerato cursado. *Educ. Quím.* **2018**, *29*, 77–88.
6. Tourón, J.; Santiago, R. Flipped learning model and the development of talent at school. *Revista Educ.* **2015**, *368*, 33–65.
7. Mohamed, H.; Lamina, M. Implementing flipped classroom that used an intelligent tutoring system into learning process. *Comput. Educ.* **2018**, *124*, 62–76. [CrossRef]

8. Moraros, J.; Islam, A.; Yu, S.; Banow, R.; Schindelka, B. Flipping for success: Evaluating the effectiveness of a novel teaching approach in a graduate level setting. *BMC Med. Educ.* **2015**, *15*, 1–10. [CrossRef] [PubMed]
9. Young, J.R. "Hybrid" teaching seeks to end the divide between traditional and online instruction. *Chron. High. Educ.* **2002**, *48*, A33–A34.
10. O'Flaherty, J.; Phillips, C. The use of flipped classrooms in higher education: A scoping review. *Internet High. Educ.* **2015**, *25*, 85–95. [CrossRef]
11. Isikoglu, N.; Basturk, R.; Karaca, F. Assessing in-service teachers' instructional beliefs about student-centered education: A Turkish perspective. *Teach. Teach. Educ.* **2009**, *25*, 350–356. [CrossRef]
12. Love, B.; Hodge, A.; Grandgenett, N.; Swift, A.W. Student learning and perceptions in a flipped linear algebra course. *Int. J. Math. Educ. Sci. Technol.* **2013**, *45*, 317–324. [CrossRef]
13. Rupakheti, C.R.; Hays, M.; Mohan, S.; Chenoweth, S.; Stouder, A. On a pursuit for perfecting an undergraduate requirements engineering course. *J. Syst. Softw.* **2018**, *144*, 366–381. [CrossRef]
14. Mason, G.S.; Rutar, T.S.; Cook, K.E. Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course. *IEEE Trans. Educ.* **2013**, *56*, 430–435. [CrossRef]
15. Sun, Z.; Xie, K.; Anderman, L.H. The role of self-regulated learning in students' success in flipped undergraduate math courses. *Internet High. Educ.* **2018**, *36*, 41–53. [CrossRef]
16. Mattis, K.V. Flipped classroom versus traditional textbook instruction: Assessing accuracy and mental effort at different levels of mathematical complexity. *Technol. Knowl. Learn.* **2014**, *20*, 231–248. [CrossRef]
17. Gilboy, M.B.; Heinerichs, S.; Pazzaglia, G. Enhancing student engagement using the flipped classroom. *J. Nutr. Educ. Behav.* **2015**, *47*, 109–114. [CrossRef] [PubMed]
18. Roach, T. Student perceptions toward flipped learning: new methods to increase interaction and active learning in economics. *Int. Rev. Econ. Educ.* **2014**, *17*, 74–84. [CrossRef]
19. González-Gómez, G.; Airado Rodríguez, D.; Cañada-Cañada, F.; Jeong, J.S. A comprehensive application to assist in acid−base titration self-learning: an approach for high school and undergraduate students. *J. Chem. Educ.* **2015**, *92*, 855–863. [CrossRef]
20. Butt, A. Student views on the use of a flipped classroom approach: Evidence from Australia. *Bus. Educ. Accredit.* **2014**, *6*, 33–43.
21. Smith, T.R.; Rama, P.S.; Helms, J.R. Teaching critical thinking in a GE class: A flipped model. *Think. Skill. Creat.* **2018**, *28*, 73–83. [CrossRef]
22. Handelsman, J.; Ebert-May, D.; Beichner, R.; Bruns, P.; Chang, A.; DeHaan, R.; Gentile, J.; Lauffer, S.; Steart, J.; Tilghman, S.M.; et al. Policy forum: Scientific teaching. *Science* **2004**, *304*, 521–522. [CrossRef] [PubMed]
23. Hargreaves, A. Mixed emotions: Teachers' perceptions of their interactions with students. *Teach. Teach. Educ.* **2000**, *16*, 811–826. [CrossRef]
24. Sutton, R.E.; Wheatley, K.F. Teachers' emotions and teaching: a review of the literature and directions for future research. *Educ. Psychol. Rev.* **2003**, *15*, 327–358. [CrossRef]
25. Tobin, K. Reproducir y transformar la didáctica de las ciencias en un ambiente colaborativo. *Enseñanza de las Ciencias* **2010**, *28*, 301–313.
26. Ross, A.A.G. Coming in from the cold: Constructivism and emotions. *European J. Int. Relations* **2012**, *12*, 197–222. [CrossRef]
27. Moffatt, K.; Todd, S.; Barnoff, L.; Pyne, J.; Panitch, M.; Parada, H.; McLeod, S.; Young, N.H. Worry about professional education: Emotions and affect in the context of neoliberal change in postsecondary education. *Emot. Space Soc.* **2018**, *26*, 9–15. [CrossRef]
28. Pintrich, P.R.; Marx, R.W.; Boyle, R.A. Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Eur. J. Int. Relat.* **1993**, *63*, 167–199. [CrossRef]
29. Vázquez, A.; Manassero, M.A. En defensa de las actitudes y emociones en la educación científica (I): Evidencias y argumentos generales. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias* **2007**, *4*, 247–271. [CrossRef]
30. Aydogan, H.; Bozkurt, F.; Coskun, H. An assessment of brain electrical activities of students toward teacher's specific emotions. *Int. J. Soc. Behav. Educ. Econ. Bus. Ind. Eng.* **2015**, *9*, 1977–2000.
31. Solbes, J. ¿Por qué disminuye el alumnado de ciencias? *Alambique* **2011**, *67*, 53–61.
32. Silverberg, L.J.; Tierney, J.; Bodek, M.J. Use of Doceri software for iPad in online delivery of chemistry content. *J. Chem. Educ.* **2014**, *91*, 1999–2001. [CrossRef]

33. González-Gómez, D.; Jeong, J.S.; Cañada-Cañada, F.; Gallego-Picó, A. La enseñanza de contenidos científicos a través de un modelo "Flipped": Propuesta de instrucción para estudiantes del Grado de Educación Primaria. *Enseñanza de las Ciencias* **2017**, *35*, 71–87.
34. Blair, E.; Maharaj, C.; Primus, S. Performance and perception in the flipped classroom. *Educ. Inf. Technol.* **2016**, *21*, 1465–1482. [CrossRef]
35. Christiansen, M.A. Inverted teaching: Applying a new pedagogy to a university organic chemistry class. *J. Chem. Educ.* **2014**, *91*, 1845–1850. [CrossRef]