Article

Flipped-OCN Method in Mathematics Learning to Analyze the Attitudes of Pre-Service Teachers

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Abstract: Due to the learning difficulties in mathematics education, a new teaching methodology have been proposed for its improvement. Difficulties in mathematics learning indicate that students are not able to properly deal with resolving calculations and/or problems. This research examines the evolution of the attitudes of pre-service teachers' (PSTs) toward mathematics learning when an open calculation based on numbers (OCN) method was followed in a flipped classroom. It was conducted in a general mathematics course, Primary Education bachelor's degree during the course of 2019/2020. A total of 143 students participated in the study (230 students enrolled), with a pre- and post-test survey questionnaire. Based on the analysis of survey questionnaires, the obtained results demonstrated that the attitudes (own beliefs and conceptions (OB), positive (ATP), and negative (ATN) attitudes) of PSTs improved positively after completing the flipped-OCN method toward mathematics learning. Regarding the statistical analyses, all questions had a significant difference that showed the influence of the flipped-OCN method, improving the PSTs attitudes toward mathematics learning ($p < 0.005$). According to the structural equation modeling—partial least squares (SEM-PLS) analysis, it demonstrated that the components relation effects of OB, ATP, and ATN of PSTs toward mathematics learning, and the influence of their educational background. Finally, with the principal component analysis (PCA), it can be found out that the science and technology background were positively correlated after the flipped-OCN method comparing with the rest of PSTs. The influence of the proposed method indicated a significant improvement in these components. Therefore, the results concluded that this study allowed to draw a promising tendency about the PSTs' attitudes toward mathematics learning with the OCN method in the flipped classroom. Additionally, these outcomes could advance our comprehension of how to help pre-service education for teachers' enhancement and maturity of positive attitudes about themselves as future teachers. Then, it would be a fundamental piece in building logical and critical thinking and development for children.

Keywords: mathematics education; OCN; attitudes; own beliefs and conceptions; PSTs; flipped learning

1. Introduction

New teaching methods for learning difficulties in mathematics education have been proposed for its improvement [1,2]. Various researchers have suggested new teaching methodologies for mathematics learning and its performance improvement [1–5]. However, students still have difficulties in mathematics learning, in fact, different studies indicate they are not able to properly deal with resolving calculations and/or problems [2,5–7]. Additionally, it shows that students' mathematics skills are not equivalent to those that tell other students of the same age [2,6,7]. A recent study confirms that learning difficulties arise before formal education [1,8]. The science and mathematics education report by the European Commission warns of declining interest in the study of science and mathematics in primary and secondary school and the need to increase demand for these studies on higher-level education, given the progress of the knowledge society [9]. Frequently, mathematical content is favored over mathematical knowledge and literacy, and students are

not encouraged to ascertain alternative answers or to chase their own solutions [10–12]. Contemporary vision of mathematical competence and education is simply associated with its notions and practices [5,13,14]. This is imperfect and naive exclusion of its collected exercise. To advance mathematical competence and proficiency, the metacognitive feature is also equivalently significant [15,16]. However, inappropriately former dominant thoughts still remain of mathematics education based on the memorization of procedure and performance, which should lead to correct responses that can be exclusive and unquestioned [13,17,18]. Therefore, with the new teaching methods and interventions, we can find out that students can overcome the learning difficulties and then achieve their mathematical contents.

In these situations, for a long time, the learning and practice of calculation have been taught and supported mechanically with a closed algorithm based on ciphers (CBC) methodology as a traditional manner in primary mathematics education [3,19]. This exercise can increase the lower order cognitive skills' development. Thus, this CBC teaching method has received some strong criticisms for basic facts of mathematics, which can undermine important learning for students [20,21]. This criticism is on the basis of the repeated rejections and passive learnings that are promoted by the CBC methodology. Here, some empirical and practical evidence show that the CBC methodology can have disadvantages to mathematics education where students cannot comprehend the fundamental operations and principles [3,21,22]. Particularly, Martínez-Montero [19] denoted the disadvantage of strategies and spontaneous methods to deal with non-routine calculation tasks, serious theoretical mistakes in calculation details, and the absence of quantities' significance of ciphers in a broader range. So, the open calculation based on numbers (OCN) is one of several alternatives to state and resolve mathematical learning problems from the CBC methodology [19,21]. One of the OCN's main characteristics is no sole means to solve problems that each student can solve a problem differently, varying on their learning level, calculation strategies and capacities, and mathematics competence and proficiency [3,5,19]. Along with the OCN methodology, instructors can apply it in the context of flipped learning presented by Bergmann and Sams, which has advanced a consideration as an alternative and active instruction method to ratify the concept and contents of the OCN in mathematics education [4,23–25]. Therefore, this methodology specifies an effective attitude improvement towards mathematics that can be prolonged [26], which is placed to develop mathematical competence and foster mathematical reasoning for students in order to increase their attention [27].

Examining students' attitudes toward mathematics learning in class can predict their proficiency and achievement [28–30]. However, scarce research of mathematics attitudes shows the current situations at best. The attitude initiated by Fishbien and Ajzen [31] was outlined as a reflected predisposition, which could respond in a constantly favorable/unfavorable method in accordance with a certain point specified [32]. As a formative item, it was deliberated in forecasting a person's performance [32,33]. Additionally, numerous studies offered that attitude effect activities were rationally ongoing, but should be deliberated and revised [28,34]. In the context of the teaching activities in flipped learning with the OCN method, their attitudes regarding mathematics education have been accredited as a great effect on the mathematics attitude, disposition, and accomplishment of students [29,35]. Principally, this methodology specified direct instructional practice, which was an efficient tool for individual entities and not for big groups [24,36]. Here, the instructor's attitude can be linked with his/her capacity. So, the pre-service teachers' (PSTs) inevitability in their capacities to present an OCN class in mathematics is exposed as a key predictor for instruction practice and exercise [37]. Accepting PST's attitudes about the OCN method in mathematics education of the flipped classroom is essential due to attaining expert views and concerted enhancement of the PSTs [24,38]. There, however, are not many dominant related research studies that have been reviewed, neither PSTs' nor in-service teachers' attitude in this specific theme. Therefore, instructing the PSTs' attitudes with the flipped-OCN learning has been a considerable element in the mathematics ed-

ucation of instructors [39,40]. Correspondingly, many works have proposed that better instructors' attitudes are greatly increasing to improve educational situations and they are greatly keener to concern original and innovative class [24].

Thus, the aim of this research is to analyze the own beliefs and conceptions and attitudes of PSTs toward mathematics learning with the OCN method in a flipped classroom environment. This work was conducted in a general mathematics course of the Primary Education bachelor's degree during the course of 2019/2020. The specific syllabus for this study contained the general mathematics topic, which was taught in the second semester 4 h/week and it was compulsory for all students. A total of 143 students participated in the study with a pre- and post-test survey questionnaire on the basis of a randomized experimental design accompanied with various statistical assessments. The relevance of this study must be found in the relation between the teaching methodology implemented in a course and the evolution of the students' attitudes toward mathematics learning, and therefore, providing empirical data to demonstrate that applying a proper teaching methodology could enhance students' own beliefs and conceptions and attitudes about mathematics.

2. Materials and Methods

In order to assess the PSTs' attitudes toward mathematics after using a OCN teaching methodology in the flipped classroom, this study was conducted in a general and compulsory mathematics subject for sophomore of the Primary Education degree. As shown in Figure 1, during the course of 2019/2020, a total of 230 students enrolled the course and among them, a total of 143 students participated (62.17%) in this study. For this research, a 5-point Likert-type scale pre- and post- on-line questionnaire were used as research instruments.
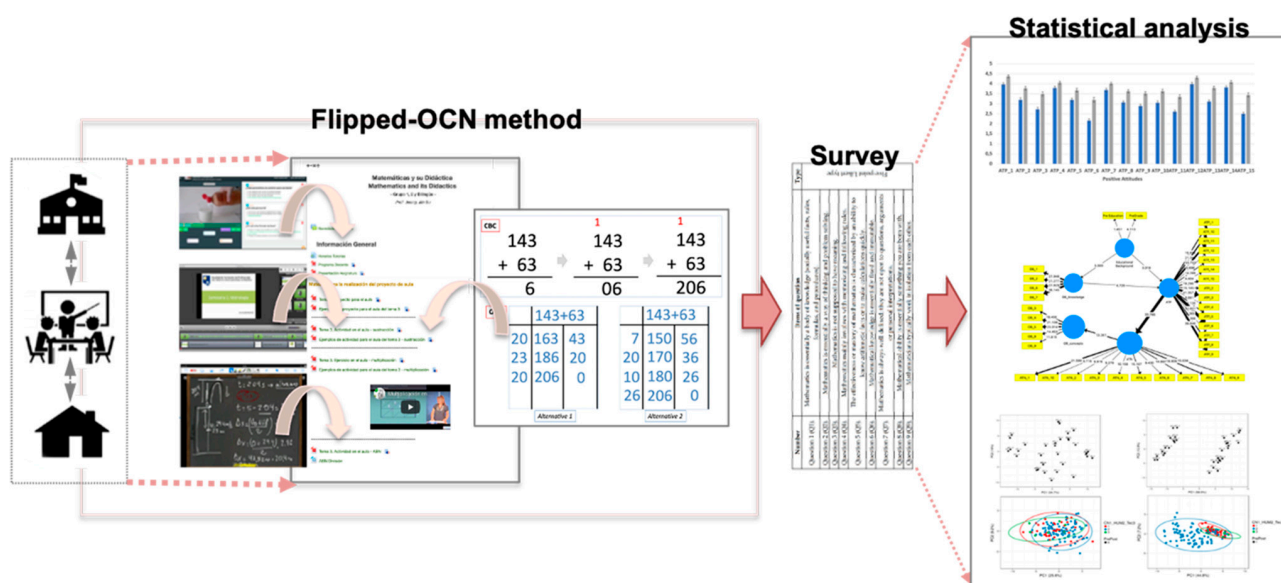

Figure 1. Research flowchart to examine pre-service teachers' (PSTs) attitudes toward mathematics learning with the flipped-open calculation based on numbers (OCN) method.

2.1. Sample

In this research, a total of 230 PSTs enrolled in the course, which was an introductory and compulsory mathematical course for a bachelor's degree in Primary Education. The study was conducted during the second term of 2019/20 course and a total of 143 PSTs participated (62.17% comparing to the original enrollment. According to the main demographic information of the participants (see Table 1), all participants had more female (51.7%) students than male students, being the participants' average age 20.4 years old. The grade point average (GPA) at the beginning of the first semester was 7.27 in a 0 to 10

scale. Regarding the educational background, 68.5% of students had a social-sciences and humanity background, 25.2% science and 6.3% technology, and almost 90% of students accessed the university directly from high school. Based on their background, it could be described that the former interaction of these PSTs with mathematics was extremely limited. Subsequently, this course could provide core information for their future instruction and they were required to have the responsibility to be educated on diverse mathematics contents and competences, improving their attitudes for primary students.

Table 1. Participants' demographic information for the research proposed.

Items		Participants
Number		143
Gender (%)	Male	48.3
	Female	51.7
Age		20.4
GPA (max. 10)		7.27
Educational Background (%)	Social Sciences/Humanities	68.5
	Sciences	25.2
	Technologies	6.3
University Access (%)	High School	88.97
	Professional School	11.03
	Test > 25	0.0
	Others	0.0

2.2. Course Context

The study was performed in an introductory and obligatory subject, entitled "Mathematics and its Didactics" which was one of core programs for a bachelor's degree in Primary Education. As shown in Table 2, this was the second-year course that contained various definitions, themes, and theories for mathematics education, especially the didactics of arithmetic. Mainly, its content had been prepared in six chapters. By means of the teaching curriculum, students required a total of 150 h for 6 credits in the expected competences. Here, it comprised of the essential features of mathematics teaching/learning, teaching/learning skills and technologies practice, mathematics history, and many ideas and thoughts of mathematics. Consequently, this course was pointing to stipulate the PSTs about general comprehension of mathematics subjects and educational disciplines and research to instruct them for primary educations students.

The course was followed by a flipped classroom teaching environment, where the theoretical contents were delivered to PSTs by means of the virtual campus, and the classroom time was employed to carry out active teaching interventions and practical demonstrations based on the OCN method, where the PSTs were requested to actively participate. Therefore, the classroom period should be considered as a student-centered setting, in which ill-defined problems, rule-based and case-based reasoning, and problem-based activities were fostered [3,19]. The collaboration and cooperation among PSTs were encouraged all the time and in all the cases. In this particular set-up of a class, the instructor position was to deliver a scaffolding to the PSTs in their work along with a short lecture if needed. Particularly, all PSTs were taught using the same intervention about the flipped-OCN method in mathematics learning, which allowed to follow the autonomous progress of each PST and postulated the possibility to develop their attitudes about mathematics education. In addition, when the PSTs had some learning difficulties, alternative quizzes and on-line questionnaires were made available to them to be addressed during face-to-face time at the classroom. Figure 1 described a flowchart of the virtual campus with the

subject contents of a syllabus chapter. Regarding the OCN materials in flipped mathematics learning, most of them applied in the class was already made before the course.

Table 2. Course context for the subject applied of the 2019/20 course.

Chapter	Course Context		
	Mathematics and Its Didactics		
	Title	Description	Hours
1	Introduction to teaching/learning of mathematics	General aspects of mathematics and its teaching. Mathematical training of PSTs. The primary curriculum for the teaching/learning of arithmetic.	16
2	Natural numbers and numbering systems	Mathematical science. Coordinable sets and number concept. Positional numbering systems. Decimal numbering. Support material for the study of numbering systems.	29
3	Arithmetic operations	Meaning and mechanism of operations. Addition and subtraction w/o compensation. Multiplications w/o regrouping. Divisions with one and several figures. Empowerment and filing. Troubleshooting. Teaching material: Abacuses and multi-base blocks.	30
4	Divisibility	Prime and composite numbers. Divisors of a number. Greatest common divisor and least common multiple. Divisibility criteria.	26
5	Fractions and the decimal numbers	Numerical expression of non-integer sets. Fractions as parts of the unit. Comparison of measurements. Operations with fractional and decimal numbers. Resources and teaching material.	26
6	Integer numbers	Positive and negative numbers. Operations with integers.	21

An example of OCN activity is illustrated in Figure 2. As it is shown, in the OCN method, there was not a sole manner to solve the calculations and it could propose various paths to get the same answer. Here, this method could highlight the flexibility aspect, which this new OCN method had no necessitates a priori indication for where the PSTs had to initiate resolving the basic calculations to achieve in answering them [26,27]. This OCN intervention was comprised of mathematics difficulties indicated by the PSTs because of teachers' expectations. In addition, this intervention dealt with more and diverse methods, which could deliver diverse approaches relying on PSTs' capacities and studying types and exercising more resources and materials of a class.

2.3. Research Instrument and Procedure to Assess the PSTs Attitudes toward Mathematics Learning

To measure individual attitudes toward mathematics learning after class intervention of the OCN method in the flipped classroom, the PSTs answered an online survey questionnaire before and after the class intervention. The questionnaire comprised of thirty-four questions grouped in three sections. This research instrument was adapted from Bardooy and Coslick [41] and Auzmendi [42]. The first group consisted of nine questions

aimed to assess the PSTs own beliefs and conceptions (OB) about mathematics learning, the second group of fifteen questions were related to assess positive attitudes (ATP) toward mathematics learning and the third groups of ten questions aimed to assess the negative attitudes (ATN) toward mathematics learning. The questionnaire followed a five-point Likert-type scale [43]: 'strongly disagreed' (SD), 'disagreed' (D), 'neutral' (N), 'agreed' (A), and 'strongly agreed' (SA). To assure the maximum contribution possible, the PSTs completed this online survey during a class session. As above-mentioned, the PSTs were requested to complete demographic aspects such as gender, age, GPA at the beginning of the first semester, educational background, and university access as basic information. The list of questions is recapitulated in Table 3, adapted from [41–43].
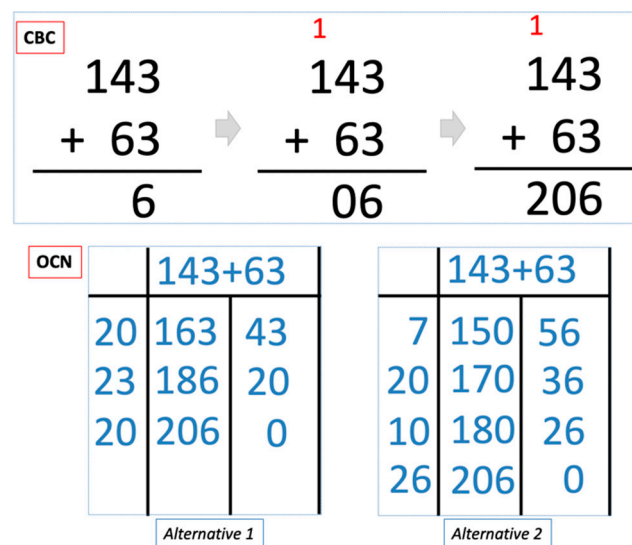

Figure 2. An example of the closed algorithm based on ciphers (CBC) and open calculation based on numbers (OCN) addition methodology for the class proposed toward mathematics learning in a flipped classroom.

2.4. Collected Data Analysis

　　All instruments and procedures were permitted by the university's bioethics board to collect the participants' information before starting the experiment. The research contribution was completely voluntary, and no particular data were scripted and documented for any participant. At the beginning of the semester, the survey questionnaire was distributed to participants (pre-test) and then the same survey questionnaire was distributed to participants when the intervention was just about to finish (post-test). Particularly, survey questionnaires were completed through an on-line manner during the classroom-time in order to increase the students' involvement. The data were concerned in order to exam if there were statistically peculiarities among the answer tendencies of participants in the pre- and post-test. With regard to the statistical analysis carried out for this study, firstly, the reliability of the questionnaire was tested by measuring the Cronbach alpha test, resulting in an alpha coefficient of 0.82 which could be determined as consistent. On the other hand, the Shapiro–Wilk normality test was conducted to establish whether the data followed or not normal distribution. As the data set followed normal distribution, parametric statistical tools were used. Thus, in order to assess the influence of the instruction followed in this study on the PSTs attitudes toward mathematics learning, a t-test was conducted (pre- and post-test). Finally, the structural equation modeling—partial least squares (SEM-PLS) and the principal component analysis (PCA) were also considered to measure the effects of the different components studied and to have a better overview of the instruction effect on the PSTs' attitudes. Lastly, a descriptive analysis was implemented to differentiate, outline, and attract conclusions from the data collected. It could describe the most suitable approach of the data [44,45].

Table 3. Survey questionnaires for the attitude of pre-service teachers (PSTs) toward mathematics learning with the flipped-OCN method.

Question	Description	Type
OB_1	Mathematics is essentially a body of knowledge (socially useful facts, rules, formulas, and procedures).	Own belief knowledge
OB_2	Mathematics is essentially a way of thinking and problem solving.	Own belief knowledge
OB_3	Mathematics is not supposed to have meaning.	Own belief concept
OB_4	Mathematics mainly involves with memorizing and following rules.	Own belief concept
OB_5	The effectiveness or mastery of mathematics is characterized by an ability to know arithmetic facts or to make calculations quickly.	Own belief concept
OB_6	Mathematical knowledge is essentially fixed and immutable.	Own belief knowledge
OB_7	Mathematics is always well defined; they are not open to questions, arguments, or personal interpretations.	Own belief knowledge
OB_8	Mathematical ability is essentially something you are born with.	Own belief concept
OB_9	Mathematicians typically work in isolation from each other.	Own belief concept
ATP_1	I consider mathematics as a very necessary subject in my studies.	Positive attitude
ATP_2	Studying or working with mathematics doesn't scare me at all.	
ATP_3	Using mathematics is fun for me.	
ATP_4	I want to have a deeper understanding of mathematics.	
ATP_5	I have confidence in myself when faced with a mathematics problem.	
ATP_6	I have fun talking to others about mathematics.	
ATP_7	Having a good knowledge of mathematics will increase my job possibilities.	
ATP_8	I am calm and collected when faced with a mathematics problem.	
ATP_9	Mathematics is enjoyable and challenging for me.	
ATP_10	I don't get upset when I have to work on mathematics problems.	
ATP_11	I would like to have an occupation in which I have to use mathematics.	
ATP_12	It gives me great satisfaction to get to solve mathematics problems.	
ATP_13	For my future, mathematics is one of the most important subjects that I have to study.	
ATP_14	If I set my mind to it, I think I would have a good command of mathematics.	
ATP_15	If I had the opportunity, I would enroll in more mathematics courses than are required.	
ATN_1	I'm pretty bad at mathematics.	Negative attitude
ATN_2	Mathematics is too theoretical to be of any use to me.	
ATN_3	Mathematics is one of the subjects I fear the most.	
ATN_4	Mathematics can be useful for those who decide to pursue a career in "science", but not for other students.	
ATN_5	When I face a math problem, I am unable to think clearly.	
ATN_6	I hope that I have little use of mathematics in my professional life.	
ATN_7	I consider that there are other subjects more important than mathematics for my future profession.	
ATN_8	Working with mathematics makes me very nervous.	
ATN_9	Mathematics makes me uncomfortable and nervous.	
ATN_10	The subject that is taught in mathematics classes is very uninteresting.	

3. Results and Discussion

In order to assess the influence of the instruction methodology implemented in this course on the PSTs attitudes toward mathematics learning, the mean values of the scores given for the pre- and post-test questionnaires were compared. As it was mentioned above, the instrument comprised three groups of attitudes: Own beliefs and conceptions about mathematics (OB), positive attitude (ATP), and negative attitude (ATN) toward mathematics learning as it is listed in Table 3. In all cases, the 5-point Likert-type scale, i.e., strongly disagreed to strongly agreed, was followed.

Figure 3 summarized the evolution of the PTSs own beliefs and conceptions before and after the flipped-OCN intervention. In all cases, the significant differences were observed ($p < 0.005$). The PSTs in the pre-test showed a mean response that was higher/lower depending on the question type than the post-test. Some question dimensions were slightly below, and other dimensions were slightly above.
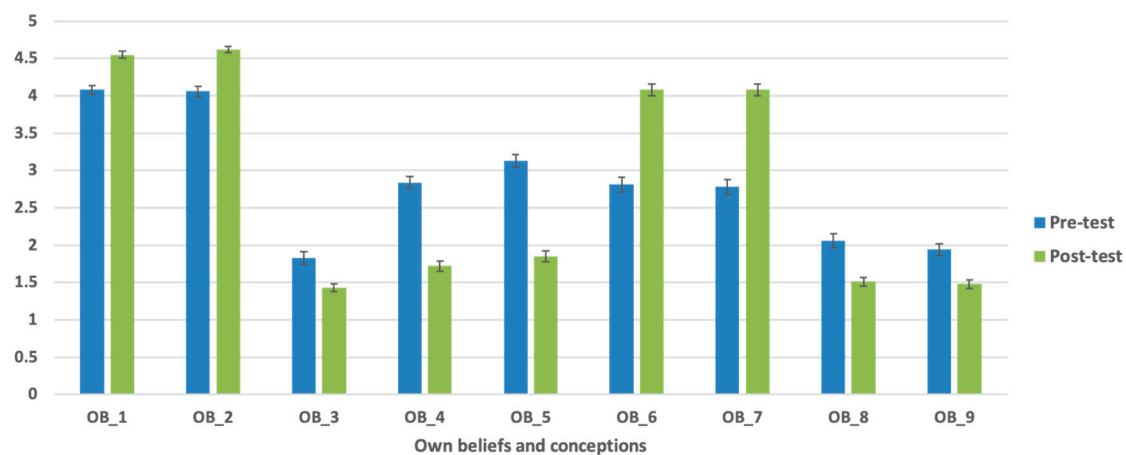

Figure 3. Mean values of the scores given for the pre- and post-test questionnaire by the 143 participants for the PSTs own beliefs and conceptions (OB) toward mathematics learning by the flipped-OCN method.

According to these results obtained, although all participants started the course with strong beliefs about the relevance of the mathematics (OB_1 and OB_2), the scores significantly improved after the flipped-OCN intervention. It was relevant to highlight OB_3, OB_4, and OB_5, which represented an evolution of the PSTs beliefs of the way of learning mathematics and were significant improved after the intervention completion. This mean a critical percentage of the data partook actively in the proposed methodology, and consequently, the opinions proposed in the study were significant to analyze the attitudes toward mathematics learning with the flipped-OCN methodology. The intervention also had a significant effect on how PSTs conceived the learning process (OB_6 to OB_9), changing from the previous conception to the learning to a more active and collaborative way.

Concerning the positive attitudes toward mathematics learning (ATP), Figure 4 summarized the results obtained after completing the study. For the 15 items, significant differences were observed for the pre- and pos-test results ($p < 0.005$). Although the participants considered that mathematics learning was somehow important for their education (ATP_1 to ATP_5) and future work possibilities (ATP_7), not many students enjoyed talking or discussing with classmates about mathematics (ATP_6) before the intervention. That attitude drastically shifted after the intervention completion. Regarding the teaching methodology, it was observed how following the flipped-OCN methodology in mathematics learning helped to increase the confidence of the PSTs to face problem solving and their confidence and keen attitude to overcome any mathematical situation (ATP_10 and ATP_12). Finally, the instruction methodology significantly increased the willingness of the students to be more exposed to mathematics learning and other non-compulsory mathematics courses (ATP_15).
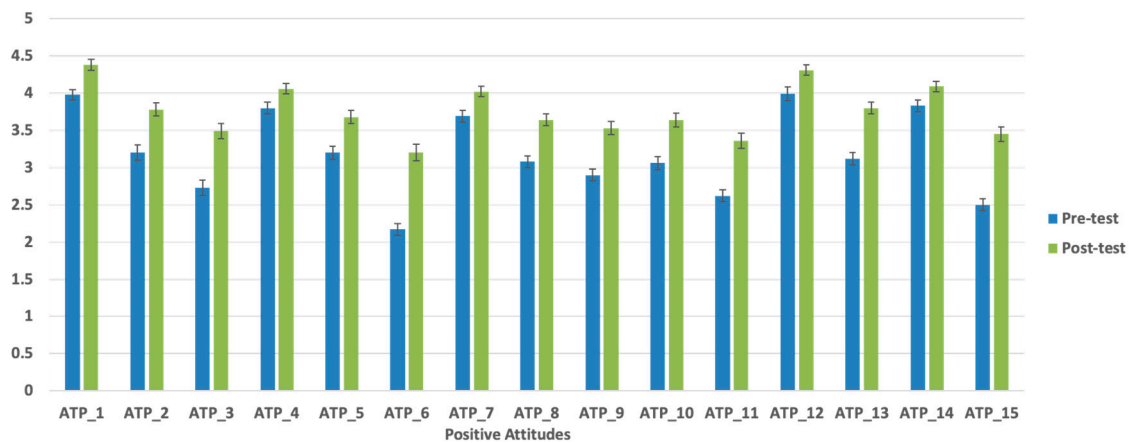
Figure 4. Mean values of the scores given for the pre- and post-test questionnaire by the 143 participants for the positive attitudes (ATP) of the PSTs toward mathematics learning through the flipped-OCN method.

Regarding the evolution of negative attitudes (ATN), Figure 5 summarized the main results obtained. As it was displayed in the figure, the instruction methodology had a significant impact ($p < 0.005$) in the attitudes' evolution, and in all cases, the PSTs provided less scores to the analyzed negative attitudes. At the beginning to the course, the participants had a stronger belief that the mathematics course was theoretical (ATN_2), difficult (ATN_3), and tough (ATN_19), and these attitudes significantly evolved to less negative after intervention completion. Moreover, the PSTs found out after completing the course that mathematics learning was not only useful for science degrees but also for all other degrees (ATN_4) or even considered that learning mathematics had the same relevance as other subjects related to teacher-trainee education (ATN_7). Finally, the PSTs attitudes toward the mathematical contents, and their attitudes toward solving and facing mathematical problems improved after the intervention completion (ATN_8 to ATN_10).
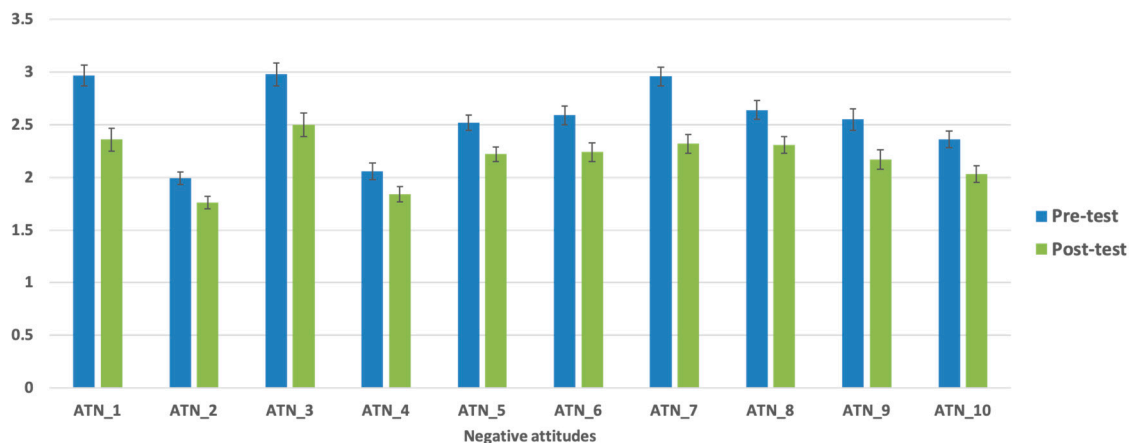

Figure 5. Mean values of the scores given for the pre- and post-test questionnaire by the 143 participants for the negative attitudes (ATN) of the PSTs toward mathematics learning by the flipped-OCN method.

The structural equation modeling—partial least squares (SEM-PLS) analysis was carried out to get a better understanding of the instruction designed on the components involved in this research: the PSTs own beliefs and conceptions, positive and negative attitudes toward mathematics learning, and the influence of their educational background. Figure 6 represented the relations between the components after applying the SEM-PLS analysis. Based on these results, the PTSs educational background had a positive effect on the positive attitudes (t-value: 3.016, $p = 0.003$) and the PTSs own beliefs and conceptions OB_1, OB_2, OB_6, and OB_7 (t-value: 3.303, $p = 0.001$). On the other hand, the positive attitudes had a strong and significant effect on the negative attitudes (t-value: 33.785,

$p = 0.000$) and finally the negative attitudes had a significant effect on the PTSs own beliefs and conceptions OB_3, OB_4, OB_5, OB_8, and OB_9 (t-value: 13.261, $p = 0.000$). Finally, the loads of each item were close to or greater than the recommended value (>0.700). Considering such values, the reliability and validity of the constructs could be granted [46].
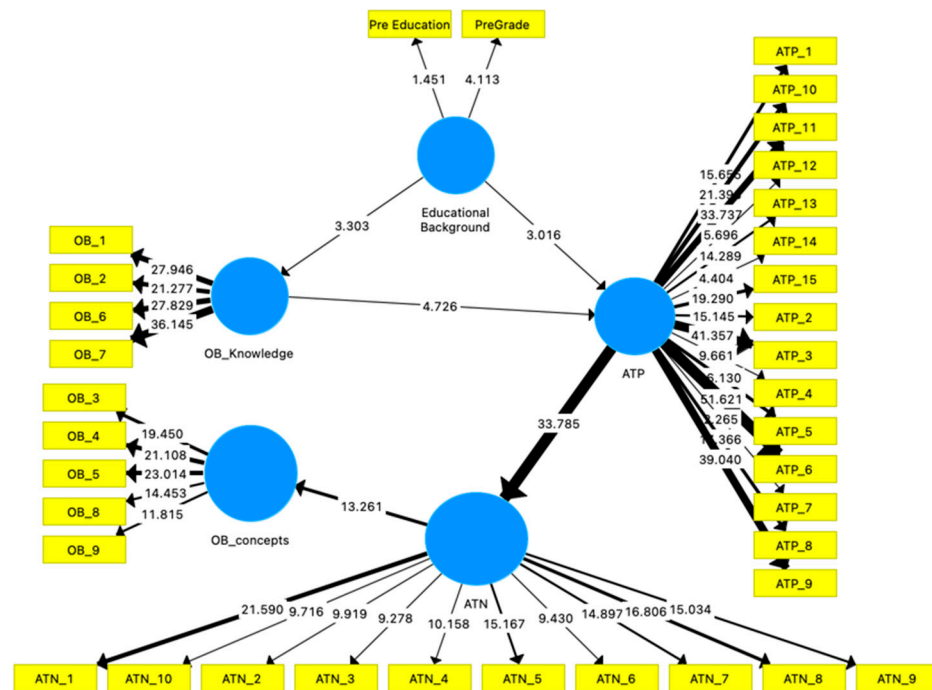

Figure 6. Results of the relation between the studied variables after applying the structural equation modeling—partial least squares (SEM-PLS) analysis and t-values are showed for the inner and outer model. Paths have been highlighted based on relative values.

Finally, in order to get a more comprehensive view of the influence of PSTs educational background on the evolution of their attitudes toward mathematics learning before and after the designed intervention, a PCA analysis were conducted. Figure 7 represented the loadings and scoring contributions plots for the pre (left) and post-test (right) data. In these graphs, ellipses and shapes in the plots showed the clustering of the sample. For the pre-test data, the principal component 1 (PC1) and principal component 2 (PC2) explained the 50% and 34.8% of the system variance for loading and scores components, respectively. On the other hand, for the post-test data, PC1 and PC2 explained the 72.4% and 52% of the system variance for loading and scores components, respectively.

The PCA diagrams showed that, at the beginning of the course, the sample did not follow any pattern concerning the attitudes assessed, nor any clustering concerning the educational background. However, once the intervention was completed, the sample was clustered into three delimited regions based on the PSTs educational background (science (red color), social sciences and humanities (blue color), and technological (green color) background). Those PTSs having a science or technological educational background were grouped on the positive axis of PC1, while the PSTs having a social sciences or humanities background were distributed in the wider region on the negative axis of PC1. Regarding the loading components plot for the post-test data, the assessed variables were grouped in two differentiated sections. On the positive scale of PC1 axis, the positive attitudes (ATP_1 to ATP_15) and as well as the following students' own beliefs and conceptions: OB_1, OB_2, OB_6, and OB_7 were clustered. On the other hand, the negative attitudes (ATN_1 to ATN_10) as well as the OB_3, OB_4, OB_5, OB_8, and OB_9 were grouped to a negative scale of PC1 axis. Comparing the scores and loading contribution plots, the social sciences and humanistic background of PTSs was more related to this second group of variables, and we had observed that these variables were significantly improved after

the intervention completion, and therefore the flipped-OCN method implemented could be a suitable strategy to foster better attitudes toward mathematics learning, especially in those students who had not been exposed to mathematics in their pre-university studies. Similar results were also reported for sciences students when a flipped classroom course was implemented [47–49].
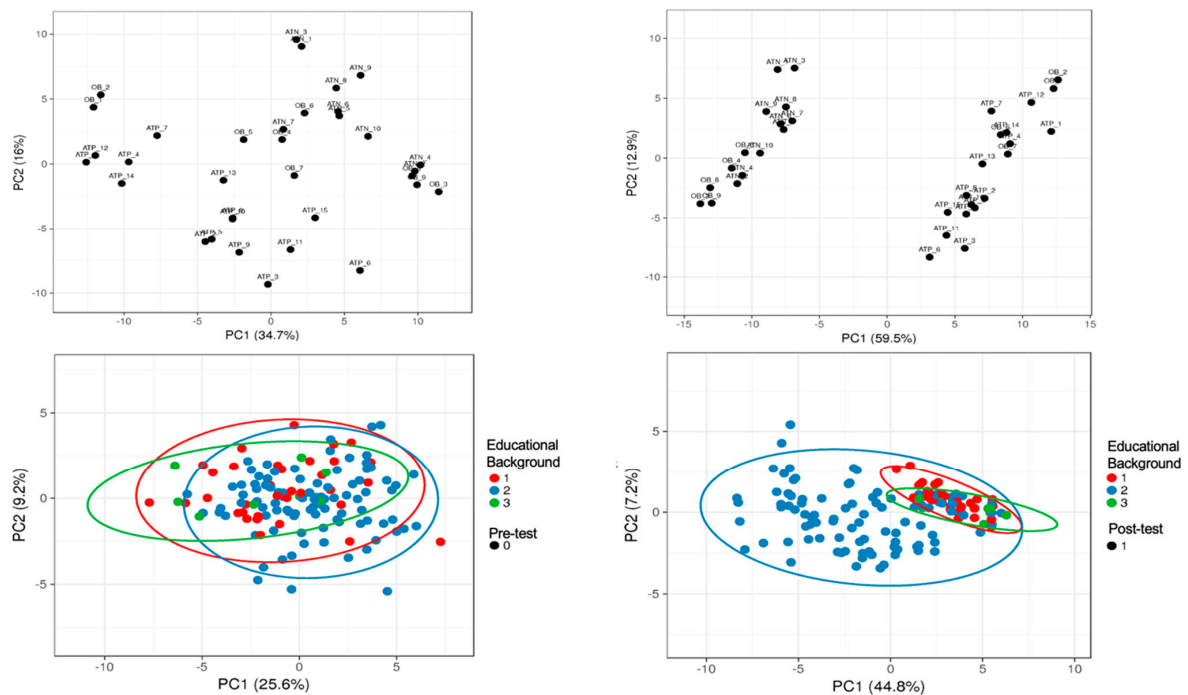

Figure 7. The principal component analysis (PCA) diagram, X and Y axis show principal component 1 and principal component 2 for the pre- (**left**) and post-test (**right**) data set. The explained variance is indicated in each plot axis. Ellipses and shapes in the score plots show the clustering of the sample at a 0.95 confidence level.

The obtained results demonstrated the novel information on the examination of the PSTs' attitudes in diverse groups and features of students toward mathematics learning with the OCN method in the flipped classroom. With the proposed methodology, this study specified the significant outcomes in the context of the analyzed questions of pre- and post-test. Consequently, the final results indicated the foremost relationships for examining the attitudes toward mathematics learning with the flipped-OCN method. Therefore, the opinions provided in the study were significant to analyze the attitudes toward mathematics learning with the OCN methodology in the flipped classroom and could be selected to examine their attitudes on account of the proposed methodology's flexible and relatable fact.

Although new teaching methods are proposed to overcome learning difficulties in mathematics education, its improvement was still an early phase and had limited application in higher education [1–5]. In these demanding and puzzling circumstances for mathematics education, various researchers have suggested new intervention methods for mathematics learning performance improvement [2–5]. Particularly, with these, students can overcome difficulties in mathematics learning that they are not able to properly deal with resolving calculations and/or problems, which arise learning difficulties before formal education [1,3,5–8]. The European Commission indicates a proposal to improve interest in the study of science and mathematics in primary and secondary school [11]. In addition, it is necessary to increase demand for these studies at higher-level education, given the progress of the knowledge society [9,11]. Here, students can discover alternative clarifications or track their own solutions [10–12] that can overcome the current view that mathematical competence is simply connected to its concepts and procedures [13,14]. Therefore, with

the new teaching methods and interventions, we can find out that students can improve their own beliefs and conceptions about mathematics learning, especially when they do have a solid mathematical background education. Additionally, the SEM-PLS and PCA analysis along with statistical outcomes can support the findings that the relation effect of the intervention proposed showed the improvement of own beliefs and conceptions.

Thus, in the current mathematics learning environment, CBC methodology is the learning and practice of calculation as a traditional manner [3,19]. Based on some strong criticisms of mathematics education that cause the lower order cognitive development of skills, CBC can undermine important learning for students as the repeated rejections and passive learning [20,21]. The new method, OCN, introduced by Martínez-Montero [19] can be a strategy and spontaneous method to deal with non-routine calculation tasks, and one of several alternatives to state and resolve mathematical learning problems from the CBC methodology [19,21]. Along with the OCN methodology, instructors can apply it in the context of the flipped learning environment which can be an alternative and dynamic education method to approve the concept and contents of the OCN in mathematics education [23–36]. It can propose an effective motivation enhancement and a reasonable change in the attitude towards mathematics [23–26]. Accordingly, this is oriented and connected to the development of mathematical competence and fostering mathematical reasoning through manipulative and motivating devices for students in order to increase attitude and attention [27]. Here, the SEM-PLS analysis showed the effects of the studied components after the intervention toward mathematics learning in the flipped-OCN method. Thus, the PCA analysis supported the confirmation that there was a dependency correlation between the outcomes of student background and their attitudes. Again, the effects were more relevant in those students with a solid mathematics educational background.

Due to these reasons and the literature and information absence, we seek to examine the attitudes of the PSTs toward mathematics learning of the flipped-OCN method. Thus, these methods are necessary to adjust flipped mathematics education with the particular OCN technique. Therefore, the instruction methodology proposed, based on the application of the OCN method in a flipped classroom environment, and the results obtained, can be utilized to reinforce the PTSs' own beliefs and conceptions toward mathematics learning, as well as improving the positive attitudes toward mathematics as well as decreasing the negative attitudes. The effects will be more relevant on those students who did not have a strong mathematics educational background.

4. Conclusions

In sum, the present research contributed to the examination and understanding of complex factors affecting the PSTs' attitudes by analyzing interrelationships among survey questions in mathematics education. This work was conducted in a general mathematics course, Primary Education bachelor's degree during the course of 2019/2020. The particular subject syllabus for this study contained the general mathematics topic, was taught in the second semester 4 h/week, and was compulsory for all students. A total of 143 students (62.17%) participated in the study, with the pre- and post-test survey questionnaire on the basis of a randomized experimental design accompanied with various assessments. On the basis of the analysis of survey questionnaires (OB, ATP, and ATN), the obtained results demonstrated that the attitudes of PSTs improved positively toward mathematics education along with the flipped-OCN method. The statistical analyses confirmed that all questions had a significant difference that showed the influence of intervention improving the PSTs attitudes toward mathematics learning ($p < 0.005$). The proposed activity influence indicated a significant improvement in these components. In the case of the SEM-PLS analysis, it demonstrated PSTs own beliefs and conceptions (OB), positive (ATP) and negative (ATN) attitudes about mathematics learning, and the influence of their educational background. Then, the PCA reiterated that a science and technology background was positively correlated after the intervention comparing with the rest of students for the methodology proposed. Therefore, the obtained results demonstrated the novel information on the

examination of the PSTs' attitudes toward mathematics learning with the flipped-OCN method. Additionally, the opinions provided in the study were significant to analyze the attitudes toward the OCN methodology in flipped mathematics learning and could support pre-service education teachers' improvement and maturity of competencies and positive attitude about themselves as teachers, which would build logical and critical thinking and development for children. As future research, the influence of the flipped-OCN method on mathematics learning should be assessed regarding the students' achievements which could reinforce the reasons and the literature and information absence.

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References

1. Butterworth, B.; Varma, S.; Laurillard, D. Dyscalculia: From brain to education. *Science* **2011**, *332*, 1049–1053. [CrossRef]
2. Hill, H.C.; Blunk, M.; Charalambous, C.; Lewis, J.; Phelps, G.; Sleep, L.; Ball, D.L. Mathematical knowledge for teaching and the mathematical quality of instruction: An exploratory study. *Cogn. Instr.* **2008**, *26*, 430–511. [CrossRef]
3. Martínez-Montero, J.; Sánchez, C. *Resolución de Problemas Y Método ABN*; Wolters Kluwer Educación: Alphen aan den Rijn, The Netherlands, 2013.
4. Jeong, J.S.; González-Gómez, D. Adapting to PSTs' pedagogical changes in sustainable mathematics education through flipped e-learning: Ranking its criteria with MCDA/F-DEMATEL. *Mathematics* **2020**, *8*, 858. [CrossRef]
5. Thames, M.H.; Ball, D.L. What mathematical knowledge does teaching require? Knowing mathematics in and for teaching. *Teach. Child. Math.* **2010**, *17*, 220–225. [CrossRef]
6. Fuchs, L.S.; Fuchs, D.; Powell, S.R.; Seethaler, P.M.; Cirino, P.T.; Fletcher, J.M. Intensive intervention for students with mathematics disabilities: Seven principles of effective practice. *Learn. Disabil. Q.* **2008**, *31*, 79–92. [CrossRef] [PubMed]
7. Fletcher, J.M.; Lyon, G.R.; Fuchs, L.S.; Barnes, M.A. *Learning Disabilities: From Identification to Intervention*; Guilford Press: New York, NY, USA, 2007.
8. Aunio, P.; Heiskari, P.; Van Luit, J.E.; Vuorio, J. The development of early numeracy skills in kindergarten in low, average and high performance groups. *J. Early Child. Res.* **2015**, *13*, 3–16. [CrossRef]
9. European Commission. Science Education for Responsible Citizenship. 2015. Available online: http://goo.gl/Vm3pZ0 (accessed on 14 November 2020).
10. Maaß, K.; Artigue, M. Implementation of inquiry-based learning in day-to-day teaching: A synthesis. *ZDM* **2013**, *45*, 779–795. [CrossRef]
11. OECD Library. Global Teaching Insights. 2021. Available online: https://www.oecd-ilibrary.org/education/global-teaching-insights_20d6f36b-en (accessed on 23 October 2020).
12. Hughes, C.; Acedo, C. *Guiding Principles for Learning in the Twenty-First CENTURY*; International Bureau of Education UNESCO: Geneva, Switzerland, 2014; Volume 28.
13. Ernest, P. Popularization: Myths, massmedia and modernism. In *International Handbook of Mathematics Education*; Bishop, A.J., Clements, K., Keitel, C., Kilpatrick, J., Laborde, C., Eds.; Springer: Amsterdam, The Netherlands, 1997; pp. 877–908.
14. Contreras, J. Where is the treasure? Ask interactive geometry software! *J. Math. Educ. Teach. Coll.* **2014**, *5*, 35–40.
15. Bruner, J.S. *The Process of Education*; Harvard University Press: Boston, MA, USA, 1977; Volume 115.
16. Noss, R.; Hoyles, C. *Windows on Mathematical Meanings: Learning Cultures and Computers*; Kluwer Academic Publishers: Dordrecht, The Netherlands, 1996.
17. Schoenfeld, A. The math wars. Educational Policy: An Interdisciplinary. *J. Policy Pract.* **2004**, *18*, 253–286.

18. Hoyles, C. Engaging with mathematics in the digital age. In *Cuadernos de Investigacion y Formacion en Educacion Matematica 15: Trabajos de la XIV CIAEM*; Universidad di Costa Rica: San José, Costa Rica, 2016; pp. 225–236.

19. Martínez-Montero, J. El método de cálculo abierto basado en números (ABN) como alternativa de futuro respecto a los métodos tradicionales cerrados basados en cifras (CBC). *Bordón. Rev. Pedagog.* **2011**, *63*, 95–110.

20. Kamii, C.; Dominick, A. To teach or not to teach algorithms. *J. Math. Behav.* **1997**, *16*, 51–61. [CrossRef]

21. Ablewhite, R.C. *Las Matemáticas Y Los Menos Dotados*; Ediciones Morata: Madrid, Spain, 1971.

22. Bull, R.; Lee, K. Executive functioning and mathematics achievement. *Child. Dev. Perspect.* **2014**, *8*, 36–41. [CrossRef]

23. González-Gómez, G.; Jeong, J.S.; Airado, D.; Cañada-Cañada, F. Performance and perception in the flipped learning model: An initial approach to evaluate the effectiveness of a new teaching methodology in a general science classroom. *J. Sci. Educ. Technol.* **2016**, *25*, 450–459. [CrossRef]

24. Bergmann, J.; Sams, A. Flipped Learning: Maximizing Face Time. White Paper. 2014. Available online: https://www.td.org/magazines/td-magazine/flipped-learning-maximizing-face-time (accessed on 21 September 2020).

25. Li, N.; Chee Mok, I.A.; Cao, Y. The evolution of mathematical thinking in Chinese mathematics education. *Mathematics* **2019**, *7*, 297. [CrossRef]

26. Garofalo, J. Beliefs and their influence on mathematical performance. *Math. Teach.* **1989**, *82*, 502–505. [CrossRef]

27. Van den Heuvel-Panhuizen, M. *Children Learn Mathematics. A Learning-Teaching Trajectory with Intermediate Attainment Targets for Calculation with Whole Numbers in Primary School*; Freudenthal Institute: Utrecht, The Netherlands, 2001.

28. Lipnevich, A.A.; MacCann, C.; Krumm, S.; Burrus, J.; Roberts, R.D. Mathematics attitudes and mathematics outcomes of US and Belarusian middle school students. *J. Educ. Psychol.* **2011**, *103*, 105–118. [CrossRef]

29. Burrus, J.; Moore, R. The incremental validity of beliefs and attitudes for predicting mathematics achievement. *Learn. Individ. Differ.* **2016**, *50*, 246–251. [CrossRef]

30. Ma, X.; Kishor, N. Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *J. Res. Math. Educ.* **1997**, *28*, 26–47. [CrossRef]

31. Fishbein, M.A.; Ajzen, I. *Belief, Attitude, Intention and Behaviour: An Introduction to Theory and Research*; Addison-Wesley: Reading, MA, USA, 1975.

32. Jeong, J.S.; González-Gómez, D.; Conde-Núñez, M.C.; Gallego-Picó, A. Examination of students' engagement with R-SPQ-2F of learning approach in flipped sustainable science course. *J. Baltic Sci. Educ.* **2019**, *18*, 880–891. [CrossRef]

33. González-Gómez, D.; Jeong, J.S.; Cañada-Cañada, F. Enhancing science self-efficacy and attitudes of Pre-Service Teachers (PST) through a flipped classroom learning environment. *Interact. Learn. Environ.* **2019**, 1–12. [CrossRef]

34. Petty, R.; Cacioppo, J. *Attitudes and Persuasion: Classic and Contemporary Approaches*; Springer: Dubuque, IA, USA, 1981.

35. Avery, L.M.; Meyer, D.Z. Teaching science as science is practice: Opportunities and limits for enhancing preservice elementary teachers' self-efficacy for science and science teaching. *Sch. Sci. Math.* **2012**, *112*, 395–409. [CrossRef]

36. Sams, A.; Bergmann, J. Flip your students' learning. *Technol. Rich. Learn.* **2014**, *70*, 16–20.

37. Oppermann, E.; Brunner, M.; Anders, Y. The interplay between preschool teachers' science self-efficacy beliefs, their teaching practices, and girls' and boys' early science motivation. *Learn. Individ. Differ.* **2019**, *70*, 86–99. [CrossRef]

38. Olakanmi, E.E. The effects of a flipped classroom model of instruction on students' performance and attitudes towards chemistry. *J. Sci. Educ. Technol.* **2017**, *26*, 127–137. [CrossRef]

39. Jeong, J.S.; González-Gómez, D. A web-based tool framing a collective method for optimizing the location of a renewable energy facility and its possible application to sustainable STEM education. *J. Clean. Prod.* **2020**, *251*, 119747. [CrossRef]

40. Kazempour, M. I can't teach science! A case study of an elementary pre-service teacher's intersection of science experience, beliefs, attitude, and self-efficacy. *Int. J. Environ. Sci. Educ.* **2014**, *9*, 77–96.

41. Baroody, A.J.; Coslick, R.T. *Fostering Children's Mathematical Power. An Investigative Approach to K-8 Mathematics Instruction*; Lawrence Erlbaum Ass: London, UK, 1998.

42. Auzmendi, E. *Las Actitudes Hacia la Matemática-Estadística En Las Enseñanzas Medias Y Universitarias*; Mensajero: Bilbao, Spain, 1992.

43. 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]

44. Jeong, J.S.; González-Gómez, D.; Cañada-Cañada, F. Students' perceptions and emotions toward learning in a flipped general science classroom. *J. Sci. Educ. Technol.* **2016**, *25*, 747–758. [CrossRef]

45. Pacheco, E.; Lips, M.; Yoong, P. Transition 2.0: Digital technologies, higher education, and vision impairment. *Internet High. Educ.* **2018**, *37*, 1–10. [CrossRef]

46. Yllana-Prieto, F.; Jeong, J.S.; González-Gómez, D. An online-based Edu-Escape Room: A comparison study of multidimensional domain of PSTs with a flipped sustainability-STEM contents. *Sustainability* **2021**, *13*, 1032. [CrossRef]

47. Jeong, J.S.; González-Gómez, D.; Cañada-Cañada, F. How does a flipped classroom course affect the affective domain to-ward science course? *Interact. Learn. Environ.* **2019**, 1–13. [CrossRef]

48. González-Gómez, D.; Jeong, J.S. EdusciFIT: A computer-based blended and scaffolding toolbox to support numerical concepts for flipped science education. *Educ. Sci.* **2019**, *9*, 116. [CrossRef]

49. Jeong, J.S.; González-Gómez, D. Assessment of sustainability science education criteria in online-learning through fuzzy-operational and multi-decision analysis and professional survey. *Heliyon* **2020**, *6*, e04706. [CrossRef]