Implementation of guides to strengthen previous conceptual weaknesses in students of Precalculus I of the UPRM, under the methodology Corequisite Support

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Abstract

This article presents the results obtained on the implementation of guidelines that were designed under the *Corequisite Support* methodology in a research carried out in Cáceres and Ortega (2022). The purpose of these guides was to explain weekly, according to the curriculum of the Precalculus I course of the University of Puerto Rico, Mayagüez Campus, the previous conceptual weaknesses (what the student should know before undergoing the Precalculus I course) of the new students of the Precalculus I course. Thus, in this study, under the methodology of *Corequisite Support,* reinforcement guides were designed to try to remedy these weaknesses. This article presents the results obtained by seven professors of the Precalculus I course in the second semester 2021 – 2022 when putting these previous reinforcement guides into practice.

Key words and phrases: Corequisite Support, Precalculus I, conceptual weaknesses.

Implementación de guías para fortalecer debilidades conceptuales previas en estudiantes de Precálculo I de la UPRM, bajo la metodología de "CorequisiteSupport"

Resumen

Este artículo presenta los resultados obtenidos sobre la implementación de las guías que fueron diseñados bajo la metodología "Corequisite Support" en una investigación realizada en Cáceres y Ortega (2022). El propósito de estas guías fue explicar semanalmente, de acuerdo al currículo del curso de Precálculo I de la Universidad de Puerto Rico, Recinto de Mayagüez, las debilidades conceptuales previas (lo que el estudiante debe saber antes de tomar el curso de Precálculo I) de los nuevos estudiantes del curso Precálculo I. Así, en este estudio, bajo la metodología de "Corequisite Support", se diseñaron guías de refuerzo para intentar remediar estas debilidades. Este artículo presenta los resultados obtenidos por siete profesores del curso Precálculo I en el segundo semestre 2021 – 2022 al poner en práctica estas guías de refuerzo previo.

Palabras y frases clave: Apoyo de correquisito, Precálculo I, debilidades conceptuales.

Introduction

In the first phase of their research, Cáceres and Ortega (2022), it was corroborated that freshman students at the University of Puerto Rico, Mayagüez Campus (UPRM), present some *conceptual weaknesses prior* to interacting with Precalculus I curriculum concepts. That is, many of the core concepts new students should know before undergoing the Precalculus I course are missing. Thus, in the first phase, these *previous concepts* (*conceptual weaknesses*) new UPRM students in Precalculus I should know and handle were identified and explained on a weekly basis.

These *conceptual weaknesses* not only provide evidence that students do not assimilate many of the concepts developed in the Precalculus I course at UPRM, but they are also main factors in student failing grades and dropout rates.

This paper summarizes the results of the continuation (or second phase) of the research published by Cáceres and Ortega (2022), which implemented *previous reinforcement* guides. These guides were developed by thirteen professors from the Precalculus I course (during the first semester 2021 – 2022) after having identified *conceptual weaknesses* students exhibited during the course. During the first phase, these thirteen professors developed guides of *previous reinforcement* to address these identified weaknesses.

The *previous reinforcement* guides followed a pattern of development, that is, each pair of professors who were responsible for the design of each of the guides that were assigned to them, were given an example of the model to follow in the design, they were mentioned that each guide should be designed to address a time of no more than 1 hour of work, and they were given instructions. Each guideline was designed by providing:

- Definitions/ properties/ and concepts (of the assigned topic).
- Examples that illustrate all the cases that each group of professors considered necessary and important, to strengthen the identified weaknesses.
- Additional support from the web, e.g., explanatory, or illustrative videos, mathematical activities (dynamic or creative) on the web, online mathematical games, or if possible, allow student groups to create their own online activity.
- Exercises as reinforcement for each of the topics included in each of the guides.
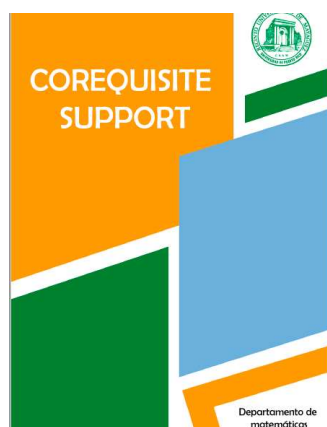

Image 1: Cover used for the design of the pre-reinforcement guides

It is important to mention that the students of this research were repeating the Precalculus I course, or simply had not taken this course for some reason, that is, these students who participated in this research were not first semester students at the UPRM. Therefore, for general purposes of the results obtained in this research, we can affirm that this study was developed with a group of students who presented many difficulties during the development of this course. In addition, it is important to mention that during the second semester 2021 – 2022 the modality in the presentation of the exams changed, since they were developed in person, unlike previous semesters where they had been developed virtually because of the health emergency promoted by the pandemic generated by COVID-19. This fact turned out to be perhaps another factor that affected students' performance.

2. Methodology

Following the Complete College America (2012) Corequisite Support methodology, five professors from the Precalculus I course participated in this research during the second semester 2021 – 2022. In total, fifteen sessions of the Precalculus I course with 195 combined students were considered. Each professor managed to establish within their groups two working groups: a *control* group, and an e*xperimental* group. The *control* group included those students who were subjected to the traditional teaching methodology of the Precalculus I course at UPRM, while the *experimental* group included those students who, despite being subjected to the traditional teaching methodology of the Precalculus I course, were also subjected to the implementation of the *previous reinforcement* guides designed under the *Corequisite Support* methodology.

In total, 89 students were assigned to the *experimental* group, while 140 students were allocated to the *control group*. However, many students did not complete the Precalculus I course, so at the end of the semester, the *experimental* group had a total of 74 students, and the control group had 121 students. Therefore, for the purpose of this study, only the results obtained for students who completed the Precalculus I course were considered. On the other hand, it is important to mention that to the fifteen sections of the working groups established by the five professors who participated in this research, four more sections of Precalculus I students were added, which belonged to two professors who had not participated in this study. That is, four more sections were added with 54 students of Precalculus I. Since these students were subjected to the traditional teaching methodology of the Precalculus I course of the UPRM, these 54 students were part of the general *control group* in this research.

For the purposes of developing this research, a *particular* and *general* analysis was implemented. For the *particular analysis*, either the *student's T* statistic (for independent samples, given the conditions in which this research was developed) and *Fisher's DMS* were implemented, using *the InfoStat* statistical software to compare the *control* and *experimental* groups for each professor. In order to establish whether there was a significant difference between the means of each of these groups, and how these differences were established between them, given the variability between the samples *final numerical grade* (on average) of each student was considered. On the other hand, to develop the general analysis a *nested or hierarchical design* was conducted in the *SAS* statistical package. For this purpose, treatment was considered as a fixed effect, and the effects of the professor and student as *a random effect*. In addition, for this last part of the analysis, not only all the grades of the students of both groups were involved for the five professors who participated in this

research, but also the numerical grades of the four sections of the two professors who had not participated in this study.

For implementing the guides, extra class periods of 1.5 hours each week were established. These extra periods were scheduled for 10 of the 16 academic weeks of the second semester 2021 – 2022. *Google Forms* were used to coordinate a common meeting date and time for these extra class periods to integrate the largest number of students possible, while minimizing scheduling conflicts with other courses.

It is also important to mention that the extra days of class that were implemented for the development of the guidelines, only covered a total of 10 of the 16 academic weeks of the second semester 2021 – 2022, as established in the first phase.

BEFORE THE EXAM I		
IMPLEMENTATION DATE	DEPLOYMENT TIME (HOURS)	GUIDE NAME
January 29	1:30	Addition and subtraction of homogeneous and heterogeneous fractions
		Decomposition of a number into its prime factors
February 5	1:30	Recognition of algebraic expressions (plus addition and subtraction)
		Product of algebraic expressions
February 12	1:30	Set notation, plus operations between "interval" sets such as joining and intercepting
		Transposition from natural language to mathematics
February 19	1:30	Types of triangles (according to sides and angles)
		Clear and apply a formula
BEFORE EXAM II		
IMPLEMENTATION DATE	IMPLEMENTATION TIME	GUIDE NAME
February 26	1:30	Regular polygons plus circle (their part, area and perimeter)
		Where the mathematical expression is defined
March 5	1:30	Verbal problems with linear functions (identifying dependent and independent variable, use of percentages and units of measurement)
March 12	1:30	Functions by parts (identification of the domain of each part, and evaluation of points)
		Evaluating algebraic expressions in functions
March 19	1:30	Reflect points or functions on $x$axis , y, or a line
		Hierarchy between functions (composite and operations).
March 26	1:30	Notion of limit of a function (asymptotes)

Figure 2: Suggested implementation timeline for Corequisite Support guides

The implementation schedule for the Corequisite Support guidelines is shown on *Figure 2*. However, as mentioned above each professor established a personalized implementation schedule with their *experimental work group*, but without straying far from the suggested schedule. This schedule was established and organized according to what was developed in the first phase to anticipate the concepts developed in the Precalculus I course until before the second exam and establish the *previous reinforcement* sought for the second phase. Thus, for each session, each professor had to cov-

er up to 2 guides of *previous reinforcement*, leaving the rest of the assignments (exercises) as a review for their students.

Due to the restrictions imposed by the COVID 19 health emergency, the Precalculus I course were held virtually during the second semester $2021 - 2022$. However, exams were administered in person. Therefore, each professor oversaw organizing the academic spaces through the Google Meet platform for meeting with their *experimental group*. At the end of this second phase, a survey was administered the students who were part of the general *experimental group* via *Google Forms* regarding aspects, such as:

- Did you participate in the *Corequisite Support* project? Answer options: Yes, No, and Partially.
- What is your $1 - 5$ satisfaction level with the *Corequisite Support* project? Answer options: 1 (not satisfactory), 2 (not very satisfied), 3 (neutral), 4 (somewhat satisfied) and 5 (very satisfied).
- Do you think that the *Corequisite Support* project helped you learn or review previous concepts for the proper development of the Precalculus I course? Answeroptions: Yes, No, and Maybe.
- Do you recommend the *Corequisite Support* project for future Precalculus I courses at UPRM? Answer options: I recommend it, I don't recommend it, and maybe I recommend it.
- What recommendations or suggestions do you have about the *Corequisite Support* project? The answers for this ítem were free and verbatim.

The answers to these questions not only allowed us to understand the success and approval achieved by students participating in the *Corequisite Support* project, but also allowed us to evaluate and improve the development of this academic project for future implementations.

3. Analysis of results

In Cáceres and Ortega (2022) researchers compared the means for both groups (*control* and *experimental*) in *a particular* way for each professor who was part of the study. For this, the statistical software *InfoStat*was used, employing the tools *T-test* for a mean and *LSD Fisher*, with a significance level for $\alpha = 0.05$.On the other hand, for the current study, we proceeded to make a *general* comparison of means between both groups, including the 4 sessions of the twoprofessors who did not participate in this study. Hence, the *SAS* statistical package was used, where a statistical model was implemented under a code of a *nested design*. Finally, the results obtained in the survey of all students taking part of the *generalexperimental* group are presented:

3.1 Comparison of means for the *control* and *experimental* groups for each professor:

The general hypothesis in this research can be defined as:

$$H_o\colon \mu_C = \mu_E$$

$$H_a\colon \mu_C \neq \mu_E$$

where μ_C corresponds to the population mean for the *control* group, and μ_E to the population mean for the *experimental* group *I*. Hence, accepting H_0 implies that the means of the *control* and *experimental* groups are equal, or that they do not show a significant difference, despite the data variability between the two groups. On the other hand, accepting H_a suggests a significant difference between the means of the groups. However, what interests us is the comparison of the means of the *control* and *experimental* groups for each professor through the *student's t* statistic and *Fisher's LSD*. Hence, the results for each professor show:

Professor 1:

Professor 1 managed two sections of Precalculus I during the second semester 2021 – 2022, with a total of 31 students, 18 were part of the *control* group and 13 of the *experimental* group. This professor reported that, in the *experimental* group, 8 of the 13 students did not participate in all the work sections. Table 1 summarizes the *student's t* results for Professor1:

```
T test for independent samples


Variable:Column2 - Class:Column1 - Test:Two tails


                           Group 1 Group 2
                           Control Expe
n                               18        13
Mean                         47,57     64,07
Variance                    904,33    593,38

Mean(1)-Mean(2)    -16,50
pVarHom                 0,4631
T                            -1,63
df                              29
p-value                  0,1144
```

Table 1: t test result for Professor 1

From the results, $T_{observed} = -1.63$ and at the time of verifying in the *table for t of student the* $T_{critical} = T_{\left(\frac{\alpha}{2}, g.l\right)} = T_{\left(\frac{0.05}{2}, 29\right)} = T_{(0.025, 29)} = 2.045$. Since $T_{critical} > |T_{observed}|$, then we must accept H_0. Similarly, we can verify this result since $p - value > \alpha$. Therefore, it is accepted that there was no significant difference between the means of the *control* and *experimental* group for Professor 1, despite the differences between the values of the means of the two groups. On the other hand, the variance for the *experimental* group suggests that it remained lower than that of the control group, suggesting greater variability of the grades in the *control* group. On the other hand, Table 2 shows the *Fisher's LSD* test.

```
Test:Fisher LSD Alpha:=0,05 LSD:=20,73247
Error: 775,6618 df: 29
Column1 Means n   S.E.
Expe     64,07 13 7,72 A
Control 47,57 18 6,56 A
Means with a common letter are not significantly different (p > 0,05)
```

Table 2: Fisher's LSD for Professor 1

The Fisher's LSD test results suggest that the means are equal, since the same letter was assigned for each mean, so there was no significant minimum difference between groups. Therefore, because of the *student's t* test and *Fisher's LSD* test, we accept the fact that the means of the *control* and experimental groups for Professor 1 do not present differences between them, except that there was less variability in the *experimental* group.

Professor 2:

Professor 2 managed two sections of Precalculus I during the second semester 2021 – 2022, with a total of 21 students, 9 of them were part of the *control* group*,* and 12 of the *experimental* group. This professor reported that the *experimental* group initially had 14 students, but that some of them withdrew from the Precalculus I course. Likewise, he mentioned that 3 of the 1 2 students of the *experimental* group did not participate in all the work sections Professor 2 provided.Table 3 summarizes the *student's t* results for Professor 2:

```
T test for independent samples


Variable:Column2 - Class:Column1 - Test:Two tails


                    Group 1 Group 2
                    Control Exp
n                         9      12
Mean                  30,94   39,07
Variance             629,01  720,29

Mean(1)-Mean(2)      -8,13
LL(95)               -32,23
UL(95)                15,97
pVarHom               0,8690
T                     -0,71
df                       19
p-value               0,4886
```

Table 3: t test result for Professor 2

Results show that $T_{observed} = -0.71$ and *t of student, the* value for $T_{critical} = T_{\left(\frac{\alpha}{2}, g.l\right)} = T_{\left(\frac{0.05}{2}, 19\right)} = T_{(0.025, 19)} = 2.433$. Since $T_{critical} > |T_{observed}|$, then we must accept H_0. Similarly,

we can verify this result since $p - value > \alpha$. Therefore, it is accepted that there was no significant difference between the means of the *control* and *experimental* group for Professor 2, despite the differences between the means of the two groups. On the other hand, the variance for the experimental group suggests that it remained higher than that of the *control* group, which proves greater variability between the grades of the *experimental* group. Table 4 shows the *Fisher's LSD* test for Professor 2.

```
Test:Fisher LSD Alpha:=0,05 LSD:=24,10007
Error: 681,8564 df: 19
Column1 Means n  S.E.
Exp     39,07 12 7,54 A
Control 30,94  9 8,70 A
Means with a common letter are not significantly different (p > 0,05)
```

Table 4: Fisher's LSD for Professor 2

The Fisher's LSD test results suggest that the means are equal, since the same letter was assigned for each mean, so there was no significant minimum difference between groups. Therefore, following the *student's t-test* and *Fisher's LSD* test, we accept the fact that the means of the *control* and *experimental* groups for Professor 2 are equal.

Professor 3:

Professor3 managed four sections of Precalculus I during the second semester $2021 - 2022$, for a total of 54 students, forty-four part of the *control* group and ten of the *experimental* group. The professor reported that the *experimental* group had 14 students, but 2 withdrew from the course. Likewise, 3 of the 10 students in the *experimental* group did not participate in all the work sections Professor 3 provided. Table 5 summarizes the *student's t* results for professor 3.

```
T test for independent samples


Variable:Column2 - Class:Column1 - Test:Two tails

                    Group 1 Group 2
                    Control Exp
n                        44      10
Mean                  26,04   49,87
Variance             348,44  528,45

Mean(1)-Mean(2)      -23,84
LL(95)               -37,53
UL(95)               -10,14
pVarHom              0,3458
T                     -3,49
df                       52
p-value              0,0010
```

Table 5: t test result for Professor 3

Results show that $T_{observed} = -3.49$ and *t of student* $T_{critical} = T_{\left(\frac{\alpha}{2}, g.l\right)} = T_{\left(\frac{0.05}{2}, 52\right)} = T_{(0.025, 52)} =$ 2.308. Since $T_{critical} < |T_{observed}|$, then the hypothesis must be rejected . Similarly, we can verify this result since $p - value < \alpha$, there was a significant difference between the means of the *control* and *experimental* group for the Professor 3. However, the variance for the experimental group suggests that it remained higher than that for the *control* group, suggesting greater variability between the grades for the *experimental* group. Table 6 shows the *Fisher's LSD* test for Professor 3.

```
Test:Fisher LSD Alpha:=0,05 LSD:=13,69619
Error: 379,5915 df: 52
Column1 Means n   S.E.
Exp      49,87 10 6,16 A
Control 26,04 44 2,94     B
Means with a common letter are not significantly different (p > 0,05)
```

Table 6: Fisher's LSD for Professor 3

The Fisher's LSD test results suggest that the means are different, since different letters were assigned for each average. This suggests there was a significant difference between groups, indicating better result for the *experimental* group. Therefore, following the *student's t-test* and *Fisher's LSD* test, it is accepted that the means of the control and experimental groups for Professor3 are different, and that the *experimental* group presented a significant difference with respect to the *control* group.

Professor 4:

Professor 4 managed four sections of Precalculus I during the second semester 2021 – 2022, for a total of 57 students, 29 part of the *control* group, and 28 of the *experimental* group. The professor reported that initially his experimental group had 30 students, likewise, he commented that 6 of the 28 students in the *experimental* group did not participate in all the work sections Professor 4 provided. Table 7 summarizes the *student's t* results for Professor 4.

```
T test for independent samples


Variable:Column2 - Class:Column1 - Test:Two tails

                    Group 1 Group 2
                    Control Exp
n                        29      28
Mean                  42,77   60,22
Variance             546,45  447,43

Mean(1)-Mean(2)      -17,44
LL(95)               -29,29
UL(95)                -5,60
pVarHom              0,6056
T                     -2,95
df                       55
p-value              0,0047
```

Table 7: t test result for Professor 4

Results show that $T_{observed} = -2.95$, and t of student $T_{critical} = T_{\left(\frac{\alpha}{2}, g.l\right)} = T_{\left(\frac{0.05}{2}, 55\right)} = T_{(0.025, 55)} = 2.304$. Since $T_{critical} < |T_{observed}|$, then H_0 must be rejected. Similarly, we can verify this result since $p - value < \alpha$. Therefore, the existence of a significant difference between the means of the *control* and *experimental* group for Professor4 is verified. However, the variance for the *experimental* group suggests that it remained lower than that for the control group, suggesting greater variability among the grades of the students in the *control* group. Table 8 shows the *Fisher's LSD* test for Professor 4.

```
Test:Fisher LSD Alpha:=0,05 LSD:=11,84708
Error: 497,8389 df: 55
Column1 Means  n   S.E.
Exp        60,22 28  4,22 A
Control 42,77 29  4,14      B
Means with a common letter are not significantly different (p > 0,05)
```

Table 8: Fisher's LSD for Professor 4

The Fisher's LSD test results suggest that the means are different, since different letters were assigned for each mean. This suggests that there was a significant difference between the means of these groups, indicating a better result for the *experimental* group. Therefore, because of the *student's t* test and *Fisher's LSD* test, it is accepted that the means of the control and experimental groups for Professor 4 are different, and that the *experimental* group presented a significant difference with respect to the *control* group.

Professor 5:

Professor 5 managed three sections of Precalculus I during the second semester 2021 – 2022, with a total of 39 students, 26 students part of the *control* group and 13 of the *experimental* group. The professor reported that the *experimental* group initially had 16 students, and 3 of the 13 students in this group did not participate in all the work sections Professor 5 provided. Table 9 summarizes the *student's t* results for Professor 5.

```
T test for independent samples


Variable:Column2 - Class:Column1 - Test:Two tails

                      Group 1 Group 2
                      Control Exp
    n                      27       14
    Mean               49,86    51,29
    Variance          426,68   624,66

    Mean(1)-Mean(2)     -1,43
    LL(95)             -16,22
    UL(95)              13,35
    pVarHom            0,3946
    T                   -0,20
    df                     39
    p-value            0,8457
```

Table 9: t test result for Professor 5

Results show that $T_{observed} = -0.21$, and t of student $T_{critical} = T_{\left(\frac{\alpha}{2}, g.l\right)} = T_{\left(\frac{0.05}{2}, 39\right)} = T_{(0.025,39)} = 2.331$. Since $T_{critical} > |T_{observed}|$ then we must accept H_0. Similarly, we can verify this result since $p - value > \alpha$. Therefore, it is accepted that there was no significant difference between the means of the *control* and *experimental* group for Professor 5, despite the differences between the two groups. On the other hand, the variance for the experimental group suggests that it remained higher than that for the *control* group, suggesting greater variety among the students' grade data in the *experimental* group. Table 10 shows the*Fisher's LSD* test forProfessor 5.

```
Test:Fisher LSD Alpha:=0,05 LSD:=14,78612
Error: 492,6716 df: 39
Column1 Means n  S.E.
Exp      51,29 14 5,93 A
Control 49,86 27 4,27 A
Means with a common letter are not significantly different (p > 0,05)
```

Table 10: Fisher's LSD for Professor 5

The Fisher's LSD test results suggest that the means are equal, since the same letters were assigned for each mean, so there was no significant difference between the means of these groups. Therefore, following the *student's t* test and *Fisher's LSD* test, we accept the fact that the means of the *control* and *experimental* groups for Professor5 are equal.

3.2 General mean comparison for *control* and *experimental* groups

To compare the mean between the *control* and *experimental* groups, we defined the following research hypotheses:

$$H_o: \mu_1 = \mu_2 = 0$$

$$H_a: \text{At least one} \mu_i \neq 0$$

where μ_1 corresponds to the population mean for the general *control* group andμ_2 to the population mean for the *generalexperimental* group. Therefore, accepting the H_0 hypothesis will imply that the two means do not present a significant difference between them, despite the variability between the two groups. On the other hand, accepting $H_a$then suggests that there is a significant difference between them. When developing this analysis using the statistical package *SAS*, and considering that it is a *nested or hierarchical design* with a fixed factor of interest (Type of Student: Experimental (Expe) or Control), the following result is obtained:

Type III Tests of Fixed Effects				
Effect	Num DF	Den DF	F Value	Pr > F
TipoEstudiante	1	255	16.51	<.0001

Table 11: General type III fixed effect test of the Student Type

Hence, we can state that since $p - value < \alpha$ then H_0 must be rejected, suggesting a significant difference between the two groups of students (*control* and *experimental*). Therefore, the effect of the experimental treatment influenced the result of the students who were subjected to the additional classes designed under the *Corequisite Support*.

T Grouping for TipoEstudiante Least Squares Means (Alpha=0.05)		
LS-means with the same letter are not significantly different.		
TipoEstudiante	Estimate	
Expe	53.9837	A
Control	40.0791	B

Table 12: Comparison of the general means of the experimental group (Expe) and control

The difference between the groups can be seen in *Table 12*, since, when comparing the means in *SAS*, different letters were assigned to each group of means, interposing the Expe group (experimental) over the control group, which suggests a greater advantage of the *experimental* group over the control group.

3.3 Responses to the survey administered to the experimental group students

A survey was administered to the **experimental group students** to collect their input on the acceptance, benefit, and transcendence of this *educational project*. This survey was carried out autonomously and anonymously using a Google Form. A total of 55 responses (of 74 possible) were received, that is, approximately 75% of the students who participated in the *experimental* groups answered this survey. The results to each question are presented below:

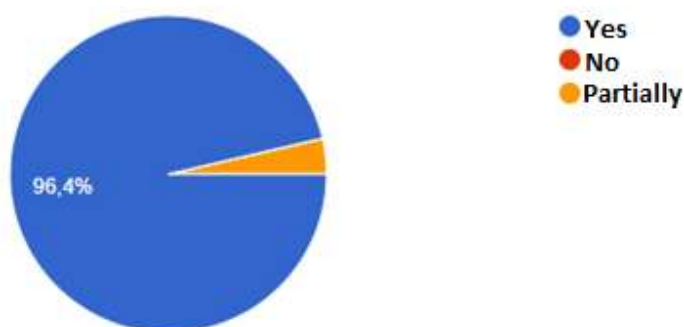Question 1: Did you participate in the Corequisite Support project?

Diagram 1: First question

For Question 1, 53 students out of 61 responded to have actively participated during the development of this project, representing 87%.

Question 2: What is your 1-5 satisfaction level with the *Corequisite Support* project? Please select an option (1 is not satisfied and 5 is very satisfied).
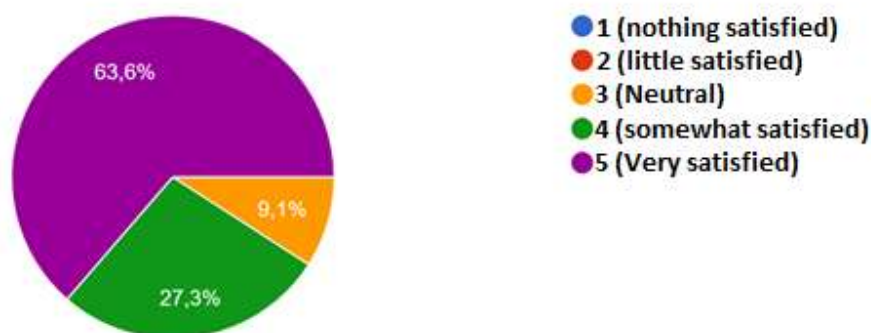

Diagram 2: Second question

For Question 2, 35 students claimed to be very satisfied with the results obtained in the project, 15 of them claimed to be somewhat satisfied, and 3 of them claimed to have a neutral position, representing a 87% of the students. So, it can be said that this research promoted the desired effect on these students, since most of them had an adequate degree of acceptance towards this *educational project*.

Question 3: Do you consider that the *Corequisite Support* project helped you learn or review previous concepts of the Precalculus I course?
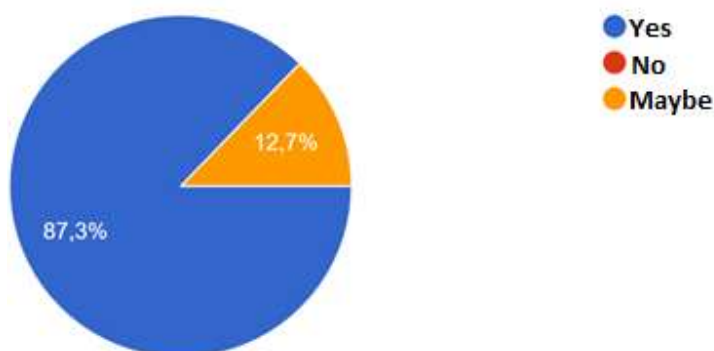

Diagram 3: Third question

For Question 3, 48 students said that the *Corequisite Support* project provided them the opportunity to learn or review previous Precalculus I course concepts, while 7 students said that this may have been the case. Therefore, the results suggest that the objective of overcoming many of the *concep-*

tual weaknesses presented by UPRM students in the Precalculus I course was achieved through the *Corequisite Support* guides.

Question 4: Do you recommend the *Corequisite Support* project for future Precalculus I courses at UPRM?
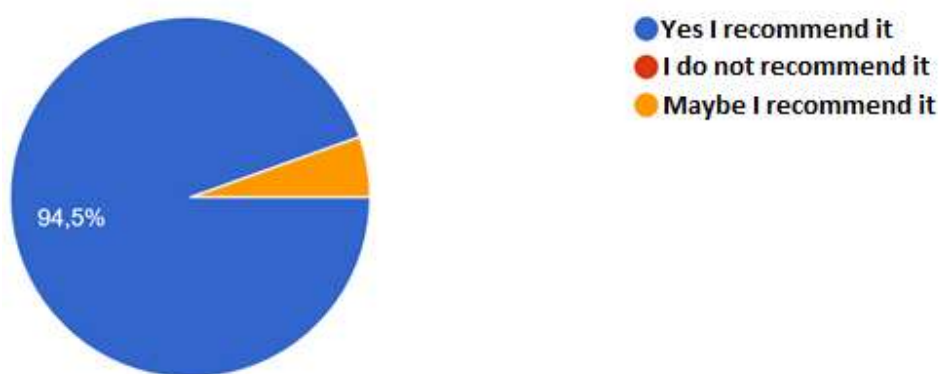
Diagram 4: Fourth question

For Question 4, 52 students stated that they would recommend the *Corequisite Support* project for future Precalculus I courses at UPRM, and 3 students stated that they may recommend it. This suggests that the effect of this study was beneficial for these students, since it not only allowed them to overcome their conceptual weaknesses, but will also help future students.

Question 5: What recommendations or suggestions do you have about the *Corequisite Support* project?

There were several responses for Question 5. Many of them stated that the program did not require any improvements; however, there were some recommendations, including:

- I would recommend that it be face-to-face, since there are people with electrical difficulties in their homes, just as in person the material is easier to understand.

- No. It has been a good support and very detailed, important concepts.

- I think the material helps to some extent. It is good to review the forgotten material of past years, but without a doubt, the program would be better if after reviewing the important things of past years, it will focus on further reviewing the concepts that come in the Precalculus I classes. This would undoubtedly have helped me to better understand the class material. However, it was a very good program and an interesting experience without a doubt.

- I understand that it should last the entire course and in person since it allows you to interact directly with the professorto clarify specific doubts with examples.

- This course was used to review; it would be good to add more days. Forexample, twice a week, etc.

- I think it would be very beneficial for us to dedicate the beginning of each class to reviewing the work of the last week. While this project was helpful, we didn't get a chance to see if the work we did during the week was correct. If we had ten minutes to review the week's work, the project would ultimately have been more useful to all of us.

- In my recommendation, some classes should be longer.

- The project should have more flexible schedules or be recorded for students who work at night and cannot join.

- The project helps you review topics learned earlier in class and refresh your memory. I recommend it because it helps you a lot in the class.

- This course was very useful. It should be extended until the end of the semester.

- Let them continue to do so.

- I think that instead of reviewing material for the previous week, it should focus on material for the current week. But the truth is that I am very satisfied with this project since the instructor explains all the details and doubts and does not load us with work.

- Corequisite *Support* is a good help, but something they should do is fix all kinds of errors in the sentences and try to be a little clearer in terms of graphics. In addition to that, the project was a good experience that helps to review concepts from previous years. To conclude, the project was very interesting and good, but the only thing I suggest that they improve are the sentences of explanation and be clearer before the procedure of the exercises that are longer or confusing.

- The *Corequisite Support* project was a phenomenal one of tremendous help to reinforce several themes and sections. -My biggest recommendation would be to also emphasize the issue of inequalities, linear equations, and factorization of polynomials. It really helped me to review more or the same as the workshops thanks to the professor's explanation and the additional information papers. 10/10

- I think it is a very well-established project, in my case it was my fault not to participate much of it, but I can say that it helped me learn and rethink some things.
- In my opinion, it covered more the sections we were currently in. But I wouldlike a little more.

According to some of the suggestions proposed by the students, we can say that the *Corequisite Support* project was thought and designed to overcome many of the previous conceptual weaknesses presented by new UPRM students in the Precalculus I course, according to the first phase results. On the other hand, some students suggested extending the project throughout the semester,

this would not be feasible because as proposed in Cáceres and Ortega (2022), the project only covers the first 10 academic weeks of the Precalculus I course. Finally, it should be noted that the research was developed during the second semester 2021 – 2022, that is, in times where the health emergency as a result of the pandemic generated by COVID-19 was still present. Hence, it would not have been possible to have complied with the suggestion of some students on conducting this project face-to-face. Although, the suggestion of recording the classes for those students who could not attend can be considered in the future.

4. Conclusions

When comparing the means of the *control* and *experimental* groups for the five professors who participated in this research, it was possible to corroborate that only two of the fiveprofessors managed to establish significant differences between their work groups, establishing an advantage of the *experimental* group over the *control* group. Particularly, although the means of the groups of each professor were different, always indicating a greater numerical advantage of the experimental group over the control group, the variability between the data between the two groups showed no significant difference when using the *student's t* statistic. On the other hand, the variances between the groups were somewhat large, which proves the variability between the data in the samples for each group. This allow us to infer that the results of this research were affected by factors, such as professor and student, since there were different results in these aspects when comparing the means in the different groups; however, for more general purposes (detaching from the previous idea) a statistical study was implemented under a *D Nested or Hierarchical* Islander.

The general comparison of means through the *Design A nested* showed a significant difference of the experimental group on the *control* group, establishing that the effect of the treatment (*experimental* group) managed to generate differences between the two groups. This suggests that students who were subjected to the traditional classes of the Precalculus I course accompanied under the *preventive support* of the guides that were designed under the methodology of *Corequisite Support*, presented a greater advantage over those students who only received traditional classes of the Precalculus I course at UPRM. Therefore, we can establish that it was possible to meet another of the objectives proposed in the first phase; since it was possible to establish a significant difference when putting into practice the *Corequisite Support* guidelines, which were the result of the first phase of this research.

On the other hand, it was possible to demonstrate the great acceptance of this research (*educational project*) by the students who formed the *experimental* groups. Their level of satisfaction was corroborated, since many of them said that this project allowed them, not only to review some previous concepts, but also to solve many of them. Therefore, this helped achieve another of the objectives proposed in the first phase of this research: the implementation of the *Corequisite Support* guides to overcome many of the conceptual weaknesses of these students. On the other hand, the students who participated in this research not only accepted this type of *educational projects*, but also proposed or recommended that they continue to be carried out as an indispensable element of the development of the Precalculus I course for future students at UPRM.

It is important to mention that during the second semester 2021 – 2022, there was a great academic disappointment in the Precalculus I course, evidenced in the student's grades, which did not exceed the minimum 65 points (on average) required to pass the Precalculus I course. Perhaps this was due to repeating students, or students who simply had not taken this course previously. Another aspect to consider may be the change in the evaluation system during the height of the pandemic promoted by COVID-19. These students were subjected to virtual classes and exams in the first semester but switched to virtual classes and face-to-face exams in the second semester. Although we cannot detract from the results obtained in this research, it would be interesting to repeat this research with a new group of Precalculus I students, who can frequently attend the work sections, and who have assimilated the change in the evaluation system.

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