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Our Learning Experience with MATH 101, a Virtual and Adaptive Remedial Course

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1. Introduction

The lack of mathematics proficiency among high school students in Guatemala is a significant concern (see [1] for details). Some students wishing to pursue a university degree in science or engineering face difficulties in their first year, as a strong background in mathematics is required to succeed in these fields. This problem is also evident at Galileo University, where many first-year engineering students struggle to pass their first mathematics course. This obstacle is even more complex; low pass rates may translate not only into demotivated students but also into high dropout rates. In recent years, Galileo University has put much effort into mitigating these issues by designing and implementing non-traditional remedial courses (e.g., [2]).

Traditional remedial mathematics courses have long been a pillar of educational institutions, allowing students to improve their mathematics skills and catch up with their peers [3]. However, these courses often rely on a one-size-fits-all approach that may only be effective for some students. Fortunately, since their introduction, adaptive learning through intelligent tutoring systems, introduced in [4], offered a new way forward. By combining technology and algorithms, we can create customized learning experiences that meet the individual needs of each student. Adaptive learning allows students to progress at their own pace and receive targeted support and feedback [5], leading to more effective and efficient learning outcomes. As a result, adaptive learning is becoming an increasingly popular and effective tool for improving mathematics skills and thus reducing the gap between struggling students and their peers. Examples of some well-known mathematics educational platforms following an adaptive learning scheme include Khan Academy [6], ALEKS [7], and WebAssign [8], among others. The main drawbacks of some of these platforms include high subscription fees, inaccurate translations to Spanish, lack of high-quality video lectures, content overload, insufficient engagement activities, and, more importantly, a limited range of topics available that may not meet the specific needs of students in Latin America.

To overcome the limitations mentioned above, we introduced in [9] an innovative remedial course called MATH 101. In essence, MATH 101 is designed to help students who still need to meet the minimum requirements for university-level mathematics courses and thus provide them with the skills needed to succeed in this area. To accomplish this objective, MATH 101 is both *virtual* and *adaptive*; it uses a diagnostic test and continuous assessment to tailor *virtual learning modules* to each student's needs. In addition to content personalization, this course integrates audiovisual material (such as over 330 video lectures) and interactive activities (based on a collection of over 2,100 problems) into 70 virtual learning modules following active learning methodologies [10] and the well-known learning-by-doing principle [11].

The main objective of this paper is to analyze the results and assess the impact of the first implementation of MATH 101. This study was conducted on a sample of 86 first-year engineering students from Galileo University who participated in this course. We evaluated two crucial aspects: *(i)* the academic benefits obtained by the students and *(ii)* their perceptions of MATH 101. More precisely, the results of the diagnostic test administered at the beginning of the course were compared with those of the final evaluation to quantify the effect of this course on students' academic performance. On the other hand, the quality of educational resources and content delivery are two aspects that are very important in every virtual course because they are correlated with students' performance. Thus, a five-point Likert scale satisfaction survey was used to assess the course interface, the quality of the educational resources, and the overall benefit of the course perceived by the students. All statistical analyses of the data collected to explore the aforementioned aspects are presented in this paper, along with their implications in the course design and future editions.

The rest of this paper is organized as follows. Section 2 presents a quick overview of MATH 101, highlighting its primary objective, content, structure, educational resources, and how its adaptive features function. The main results regarding educational benefits and students' perceptions of the first implementation of our remedial course are presented, analyzed, and discussed in Section 3. Finally, in Section 4, we draw some conclusions and present our future work.

2. A Quick Overview of MATH 101

MATH 101 is a *self-paced* and *asynchronous* remedial course that personalizes the content to each student's needs based on constant assessment. The main objective of MATH 101 is to reinforce the mathematical skills that students acquire in high school, thus making the transition from high school to university-level mathematics courses as smooth as possible. To accomplish this objective, MATH 101 covers all topics that every first-year engineering student must master to excel in our first engineering mathematics course, MATH 201. MATH 101 follows a detailed segmentation of its content as required by the Active Topic Centered Learning (ATCL) methodology introduced in [12]. Therefore, MATH 101 was divided into four *units*, each subdivided into *topics*. In the following, we summarize the key subjects covered in each course unit and the number of topics that constitute each.

- *Unit 1 - From Arithmetic to Algebra (26 topics):* This unit covers the concepts of number and numerical sets, including divisibility, prime factorization, greatest common divisor (gcd), least common multiple (lcm), as well as properties of real numbers, the real line, and the absolute value. This unit also includes a review of fundamental arithmetic, including fractions, powers, roots, and the order of operations.

- *Unit 2 - Algebra of Real Numbers (14 topics):* This unit covers the basics of algebra, including its terminology, basic operations with algebraic expressions, factorization, and operations with rational expressions.

- *Unit 3 - Simple Mathematical Models (12 topics):* This unit introduces the topics of equations and inequalities, including linear and quadratic equations and systems of linear equations. It also covers problem-solving principles and the use of equations and inequalities for simple mathematical modeling.

- *Unit 4 - Elements of Trigonometry (18 topics):* This unit includes topics related to angles and their measurement, properties of triangles such as congruence and similarity, theorems such as Thales's theorem and Pythagoras theorem, trigonometric ratios, introduction to basic trigonometric identities, and the solution of right-angled and oblique triangles.

MATH 101 is built on *virtual learning modules designed* for each course topic. Each module includes the following educational resources:

- *Theoretical/demonstrative videos:* include a short lecture on the theoretical aspects of the single topic under discussion, including definitions, theorems, and selected proofs.
- *Practical videos:* include a detailed explanation of sample problems illustrating the topic presented in the theoretical videos.

- *Topic-Designed worksheet:* contains theoretical questions, exercises, and word problems related exclusively to the module's topic. The different activities included in these worksheets were designed to put the concepts learned in the video lectures into practice and to evaluate the student's understanding of the topic. It is important to emphasize that, based on the results obtained from these worksheets, the platform decides whether the student is ready to move on to the next module in his/her learning path or needs to study the topic via video lectures before continuing. Note that since the student may solve the worksheet in multiple attempts, the worksheets are randomly selected from a bank of problems. In the first edition of MATH 101, such a bank includes a total of over 2100 problems for the whole course.

Before presenting the main results of the first implementation of MATH 101, it is essential to understand how this online course adjusts its content according to each student's needs through ongoing assessment. When a student is enrolled in MATH 101, the course platform performs the following steps.

- *Step 1:* The course begins with a (non-standardized) *diagnostic test* that evaluates concepts, operatory, and problem-solving skills in the following areas: *(i)* arithmetic, *(ii)* algebra, *(iii)* simple mathematical models (equations and inequalities), and *(iv)* elements of trigonometry. Notice that this test was divided into four sections corresponding to the four units of the course. This test has 60 questions, including single- and multi-select multiple-choice questions.

- *Step 2:* The course platform analyzes the results from the diagnostic test and creates the *student's initial profile*, summarizing the student's strengths and weaknesses in the four areas mentioned above.

- *Step 3:* Based on the *student's initial profile,* the course platform designs a personalized *learning path* for each student. This path consists of the course units the student needs to complete to improve any deficiencies identified by the diagnostic test.

- *Step 4:* The course platform conducts the student to the first unit and module in his/her learning path. Each module starts with a worksheet composed of exercises and problems that evaluate the student's knowledge of the module's topic. If the student can solve the problems presented in the worksheet, the platform determines that he/she knows the topic and moves them to the next module; otherwise, the platform presents the module's content to the student so that he/she can study this material before attempting to solve the worksheet again. It is worth mentioning that the student can attempt to solve the worksheet multiple times, but they are encouraged to seek help through the course's discussion forum if necessary.

- *Step 5:* When a student completes all the units and modules in his/her unique learning path, a (non-standardized) final test is administered to generate the student's *final profile*, which is expected to meet all the prerequisites for MATH 201.

To conclude this section, we refer the interested reader to [9] for more details regarding the content, structure, educational resources, and implementation of MATH 101.

3. Main Results and Discussion

The main objective of this study is to analyze the outcomes and measure the academic influence of the first implementation of MATH 101. We are also interested in evaluating the student's learning experience throughout this course to enhance its future editions. Therefore, the impact of this innovative remedial course was determined by considering two key aspects: *(i)* academic benefits and *(ii)* students' perceptions. The following two subsections discuss these aspects in detail. All the data analyzed in this study were collected from a sample of 86 first-year engineering students from Galileo University who were enrolled in MATH 101 during the first semester of 2022. Our sample contains students from different engineering specializations such as computer science, electronics, mechatronics, telecommunications, chemistry, industrial, and management.

a. Academic Benefits

We divided the data analysis into two parts to establishing the academic benefits that MATH 101 provided to the students enrolled in this course. The first part presents the main results from comparing the student's *initial profile* with the *final* one, along with the student's grades in MATH 201. In the second part, we discuss the relevant aspects obtained from analyzing some of the multiple parameters collected by the course platform, giving rise to a detailed topic-by-topic assessment.

i. Initial Student's Profile versus Final Student's Profile

Recall that MATH 101 starts with a non-standardized diagnostic test covering topics in four areas. The grades (over 100 points) in each area and their average constitute the *student's initial profile*. Similarly, the course ends with the same non-standardized evaluation, and, again, the grades in each area and their average give rise to the *student's final profile*. Since MATH 101 is divided into four units covering the areas mentioned above, a natural way to estimate the impact of our remedial course is to analyze the students' grades in such tests.

Figure 1 presents a comparison of the grades obtained on the diagnostic test (*initial profile*) versus the results obtained in the same evaluation but after finishing with MATH 101 (*final profile*). This figure includes the descriptive statistics, box plots, and kernel density plots of such grades. Note that the average grade increased from 48.62 to 77.36 points, an increment of approximately 59%, while the standard deviation showed a reduction of roughly 34%. The density plot illustrates this fact, as the final grade distribution is to the right of the initial one, being the final narrower. These numerical results imply that MATH 101 had a significant impact on most students. More precisely, MATH 101 started with a group of students with noticeable deficiencies in mathematics and diverse backgrounds. However, by the end of our remedial course, the students showed proficiency in the final exam. As a consequence, the statistical evidence indicates that some of the objectives of MATH 101 were fulfilled since the course ended with a better-prepared group of students with similar backgrounds in mathematics.

One of the main objectives of MATH 101 is to prepare students for MATH 201. Therefore, a natural question is: how did the students who completed MATH 101 *satisfactorily* perform in MATH 201? Completing MATH 101 "satisfactorily" means that the student finished all the activities in all the modules of his/her virtual learning path and obtained a grade above or equal to 61% in the final course evaluation. To answer the above question, we collected the final grades of MATH 201 for every student in our sample. Interestingly, only one of those students dropped out of MATH 201. Our findings are encouraging; 61% of the students that completed MATH 101 satisfactorily approved not only MATH 201 but also obtained an average grade of 77.72 (out of 100) points. As a result, this analysis indicates that MATH 101 allows the students to reinforce their knowledge of basic mathematics and prepare them for the first university-level mathematics course.

On the other hand, many reasons may have affected the performance of those students that, despite completing MATH 101 satisfactorily, they did not approve MATH 201. Among them, we can mention: *(i)* the violation of academic integrity when completing the activities in MATH 101, *(ii)* a student may require more time and additional practice than the one provided by MATH 101 to grasp a concept, and *(iii)* the lack of motivation and engagement, among others. Further study is required to examine these peculiar cases. Constructing a predictive model is part of our future research plan; this will provide us with more insights regarding the probability of success in MATH 201 after a student has completed MATH 101.

The diagnostic test segmentation into the four areas of MATH 101 allows us to explore further and establish its impact in each one. Figures 2, 3, 4, and 5 present the descriptive statistics along with boxplots and kernel density plots of the students' initial and final profiles of each of the four main topics covered in our remedial course. In the area of arithmetic, the average grade increased from 49.49 to 68.74 points, which is an increment of approximately 39%, while the standard deviation showed a reduction of roughly 41% (see Figure 2). The average grade in algebra increased from 53.53 to 82.60 points (an increment of roughly 54%), and the standard deviation was reduced by 32% (see Figure 3). In the area of simple mathematical models, the average grade increased from 58.28 to 89.07 points, which is an increment of around 53%, and the standard deviation was reduced by 42% (see Figure 4). Notice that, of the four areas evaluated, trigonometry is the topic that is more challenging for the students in our sample since they initially obtained an average grade of 33.16 points (see Figure 5). However, the average grade increased to 69.02 in the final exam, although the standard deviation is very similar to the initial one. This fundamental statistical analysis suggests that basic arithmetic and trigonometry are the two areas that require additional attention and effort for most students, while simple mathematical models seem to be less challenging for them. In summary, these quantitative results translate into a meaningful improvement in basic operational and problem-solving skills in all the areas covered in MATH 101, constituting the cornerstone of our first engineering mathematics course.

Diagnostic Test		
Statistics	**Final Profile**	**Initial Profile**
Mean	77.36	48.62
Median	77.50	50.00
Mode	74.00	54.00
Standard Deviation	9.65	14.68
Kurtosis	0.01	-0.38
Skewness	-0.52	-0.42
Range	44.00	65.00
Min	52.00	8.00
Max	96.00	73.00

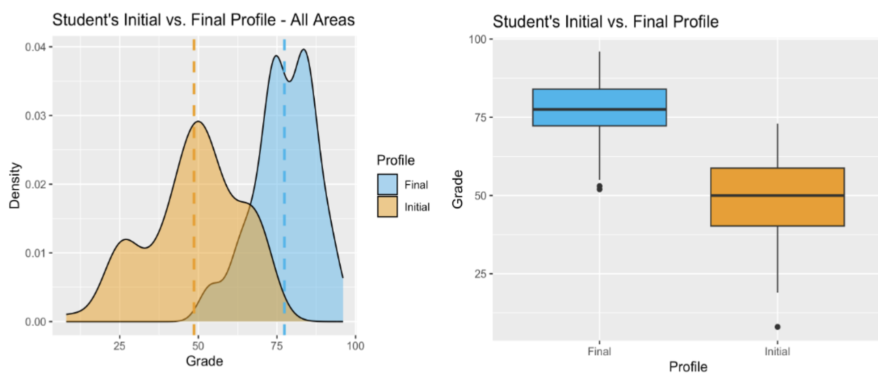


Figure 1 - Descriptive statistics and comparative plots of the student's initial and final profile, including all areas.

From Arithmetic to Algebra		
Statistics	**Final Profile**	**Initial Profile**
Mean	68.74	49.49
Median	68.00	54.00
Mode	68.00	72.00
Standard Deviation	11.67	19.75
Kurtosis	0.79	-1.01
Skewness	0.04	-0.29
Range	60.00	72.00
Min	36.00	12.00
Max	96.00	84.00

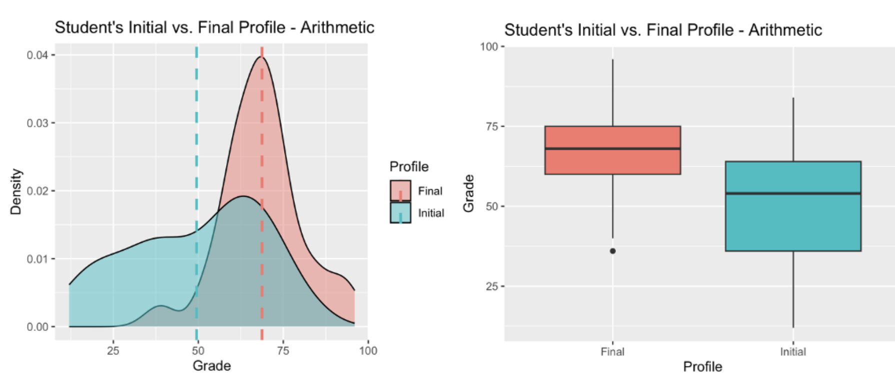
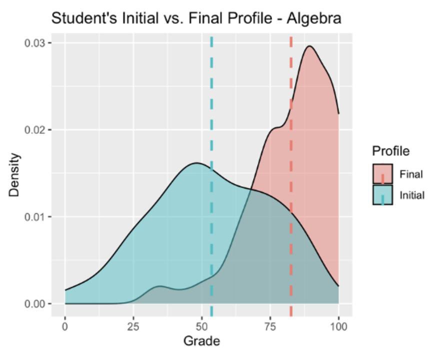


Figure 2 - Descriptive statistics and comparative plots of the student's initial and final profile in arithmetic.

Algebra of Real Numbers		
Statistics	Final Profile	Initial Profile
Mean	82.60	53.53
Median	88.00	52.00
Mode	100.00	48.00
Standard Deviation	15.00	22.00
Kurtosis	1.41	-0.63
Skewness	-1.13	-0.18
Range	68.00	92.00
Min	32.00	0.00
Max	100.00	92.00



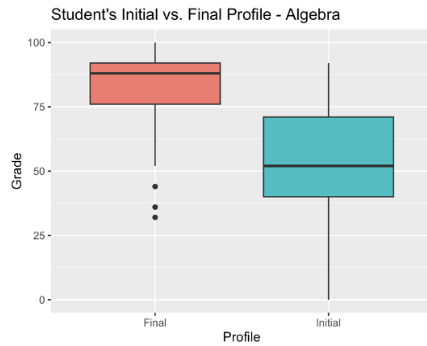
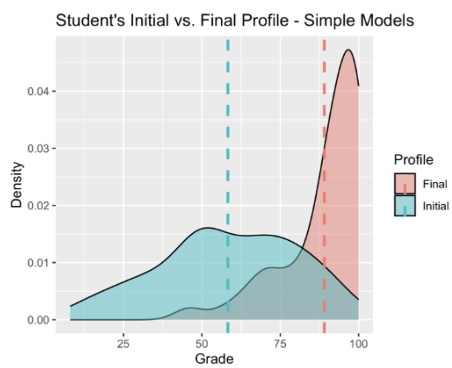


Figure 3 - Descriptive statistics and comparative plots of the student's initial and final profile in algebra.

Simple Mathematical Models		
Statistics	Final Profile	Initial Profile
Mean	89.07	58.28
Median	92.00	58.00
Mode	100.00	48.00
Standard Deviation	12.80	21.92
Kurtosis	2.09	-0.64
Skewness	-1.56	-0.25
Range	56.00	92.00
Min	44.00	8.00
Max	100.00	100.00



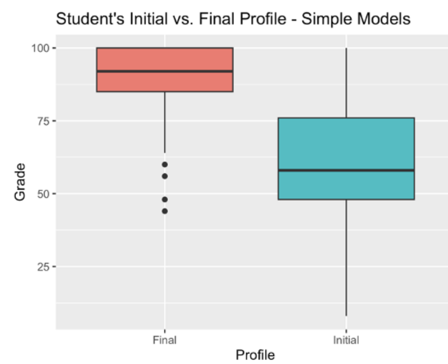


Figure 4 - Descriptive statistics and comparative plots of the student's initial and final profile in simple mathematical models (equations and inequalities).

Elements of Trigonometry		
Statistics	Final Profile	Initial Profile
Mean	69.02	33.16
Median	68.00	28.00
Mode	68.00	44.00
Standard Deviation	20.41	23.32
Kurtosis	-0.49	-0.50
Skewness	-0.33	0.53
Range	80.00	92.00
Min	20.00	0.00
Max	100.00	92.00

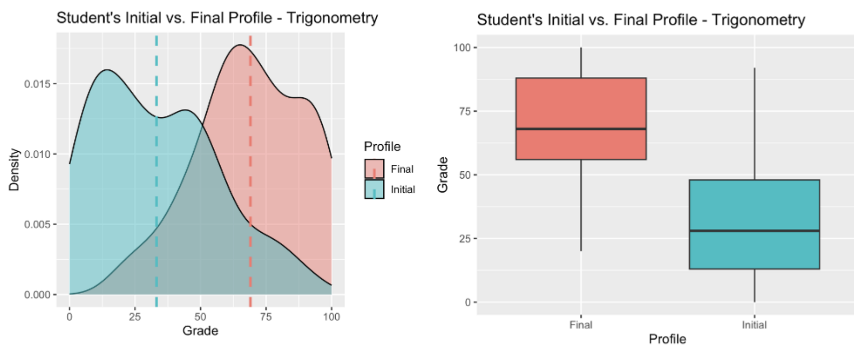


Figure 5 - Descriptive statistics and comparative plots of the student's initial and final profile in elements of trigonometry.

ii. Topic-by-topic Analysis

Recall that MATH 101 is divided into four units, each subdivided into virtual learning modules covering a single topic at a time. Each module includes a Topic-Designed worksheet (see Section 2) to evaluate the student's domain of the subject under discussion. In this subsection, we analyze some of the data collected by the platform for each module's worksheet, considering parameters such as:

1. The *maximum* and *minimum average scores* obtained by the students,
2. The *average number of attempts* required by the students to solve it successfully, i.e., obtain a score above 61% on the worksheet,
3. The *average improvement*, i.e., the difference between the highest and lowest average scores.

It is worth mentioning that, typically, the *minimum score* corresponds to the student's first attempt to solve the worksheet, where no educational resources are available. In other words, these results come exclusively from the student's prior knowledge. In contrast, the *maximum score* may match the student's final try, i.e., when the student solves the worksheet successfully after studying MATH 101's material. Of course, there are cases where the students only require a single attempt to solve the worksheet satisfactorily; in these cases, the minimum and maximum scores are equal. Finally, note that the *average number of attempts* is a relative measure of the topic's difficulty; the closer to 1, the easier it was for the student to pass to the next module.

With the following topic-by-topic analysis, we can explore deeper than in the previous section by determining which topics seem difficult for students. This analysis also provides valuable insights regarding which modules may require additional educational resources to help students better. To summarize our findings, we present two graphs: *(i)* a bar chart showing the average minimum and maximum scores per topic (see Figure 6) and *(ii)* a line graph showing the average number of attempts per topic (see Figure 7). The results illustrated in Figures 6 and 7 are analyzed below for each of the four units of the course.

Unit 1 - Arithmetic: Figure 6 shows that the topic with the most significant improvement corresponds to Topic 2 (Prime Factorization), while Topic 26 (Order of Operations) presents the slightest difference on average. Topic 2 is also where the students seem less prepared since the minimum average score was 52.98%. The concept of prime factorization is essential for understanding the factorization of polynomials later in algebra. In contrast, in the worksheet from Topic 14 (Addition of Fractions), the students obtained a minimum average grade of 93.45%, thus showing proficiency from the beginning. Notice also that the only topic where the maximum average achieved was 100% is Topic 5 (Applications of the Greatest Common Divisor and the Least Common Multiple). Figure 7 shows that Topics 5 and 6 (Number Sets) were the only ones requiring the students to make more than three attempts on average to succeed. Interestingly, Topic 21 (Definition of Radical) demanded the least average number of tries (1.07) to approve it. Notice that 12 out of 26 modules required more than 1.5 attempts on average for the students to master these topics. Arithmetic is associated with critical misconceptions about numbers and their operations [13], so errors are often constant and unnoticed by students.

Unit 2 - Algebra: Figure 7 shows that Topic 2 (Definitions of Monomials and Polynomials) is one of the most complex topics in the course for our students since it required almost six attempts on average for the students to succeed. In our experience, high school mathematics courses put much emphasis on operative exercises, neglecting the conceptual ones, as demonstrated by the excellent results obtained in Topics 5 (Notable Products), 7 (Factorization), 8 (Division of Polynomials), and 13 (Multiplication and Division of Algebraic Expressions). However, when more complex algebraic expressions are involved, such as those in Topic 14 (Simplification of Fractional Expressions), the students struggle more, taking 3.09 attempts on average to solve those problems. Thus, throughout the course, we introduce several theoretical questions to identify and prevent the most common misconceptions in algebra; this will help students learn algebra correctly and understand what they are doing [14]. Finally, Figure 6 shows that the maximum average results for almost all of the topics in this unit are above 75%; this means that the educational resources met their objective.

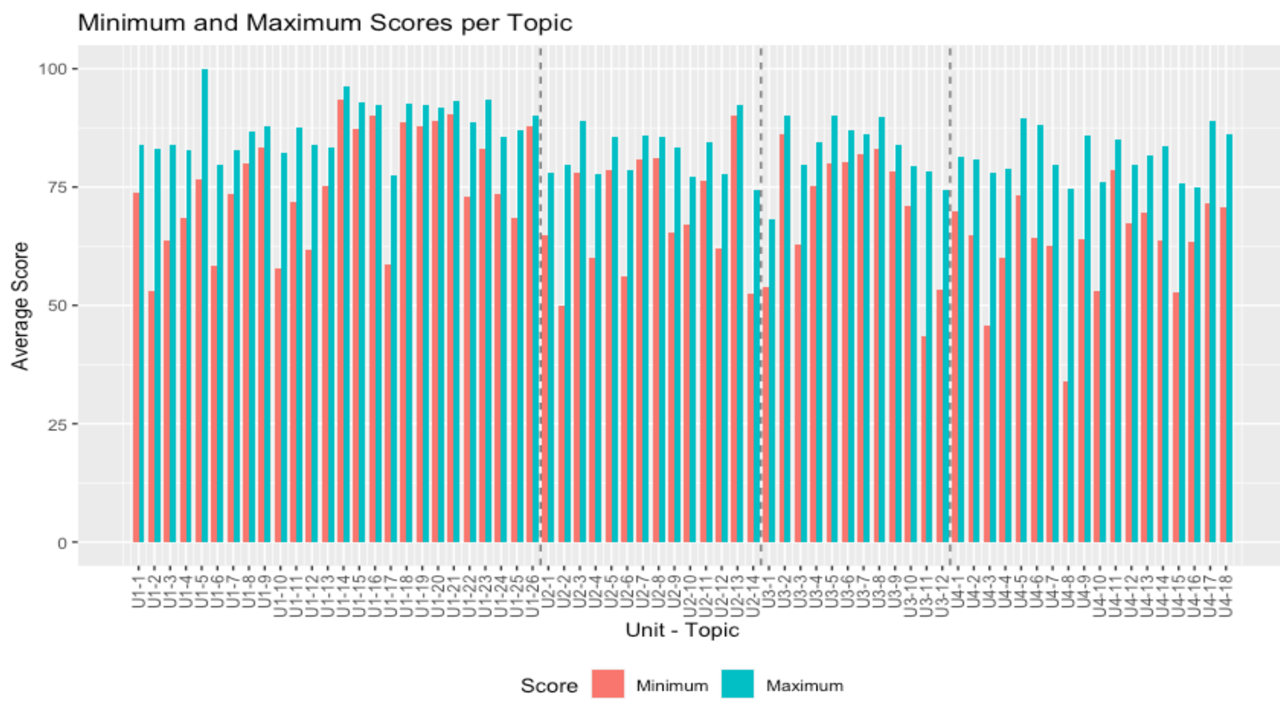


Figure 6 - Bar chart with the minimum and maximum average scores per topic in the four units of MATH 101.

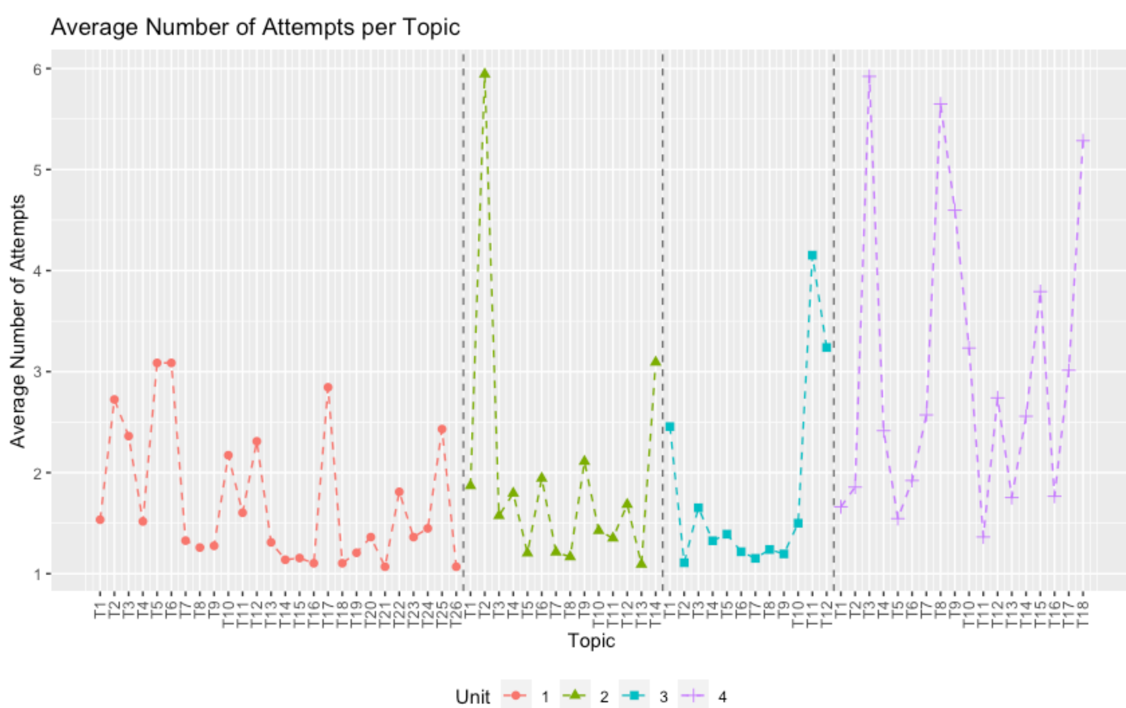


Figure 7 - Line chart with the average number of attempts per topic in the four units of MATH 101.

Unit 3 - Simple Mathematical Models: Figure 6 shows that Topic 11 (Modeling with Equations and Inequalities) has the most significant improvement, while Topic 2 (Linear Equations) presents the slightest enhancement on average. Topic 11 is also where the students seem less prepared since the minimum average score was 43.38% and the average number of attempts to succeed was 4.15, significantly higher than those from the rest of the topics in this unit (see Figure 7). Topic 12 (Solving World Problems) also presented difficulties to the students since it is linked to the previous one. In Topic 11, the students are only asked to translate word phrases into algebraic expressions, while in Topic 12, they are moved a step forward by asking them to solve the problem completely. These results demonstrate that the resolution of word problems is an opportunity for students. While most students may solve a linear/quadratic equation (or inequality) easily (covered in Topics 2 to 9), it is hard for them to choose the right mathematical model to solve a problem [15]. Finally, the student's difficulties with conceptual questions are again present in this unit. Topic 1 (Introduction to Equations), where the basic terminology of equations is introduced, took the students 2.46 attempts on average to answer the questions correctly; this number is above the mean of the more operative modules (Topics 2 to 9) with an average of 1.29.

Unit 4 - Trigonometry: Figure 6 shows that Topic 8 (Congruent Triangles) has the most notable improvement, while Topic 11(Pythagorean Theorem) presents the minimum change on average. Topic 8 also has the minimum average score (33.96%) in all the course modules. These results coincide with our experience; "Right Triangles" is often reinforced throughout high school, while more conceptual topics such as "Congruent and Similar Triangles" are commonly not profoundly studied. Figure 7 illustrates that different from the other three units, the average number of attempts to solve the worksheets of this unit increased significantly to 2.98. Topics 3 (Applications of Angles), 8 (Congruent Triangles), 9 (Similar Triangles), 10 (Thales's Theorem), 15 (Applications of Right Triangles), 17 (Oblique Triangles), and 18 (Applications of Oblique Triangles) required the students three or more attempts to show proficiency. In general, trigonometry is a high school subject disliked and mastered by very few students; while most students find it challenging, others strongly dislike it [16]. This perception may explain the overall behavior of the students throughout this unit.

b. Student's Perception

Several factors are critical in the design of a virtual course. For example, the quality of the educational resources, the effectiveness of content delivery, user experience with the course interface, feedback provided to the students, and interaction with peers ensure that the students have a learning experience that promotes their academic success [17, 18, 19]. Since all these aspects strongly correlate with the student's academic performance, they should not be overlooked. To determine the students' perception of these aspects and rate their overall experience with MATH 101, a five-point Likert scale satisfaction survey, based on the Computer

System Usability Questionnaire (CSUQ) [20], was administered at the end of the course. This survey was divided into four sections, whose details are given below.

Section 1 - Usability: This section measures the students' overall satisfaction with the course and their perception of its effectiveness. Figure 8 summarizes the questions asked in this part of the survey, along with the results obtained. Notice that all the items in this section obtained a score above or equal to 75%, except for the last question. Thus, most of the students seemed to be satisfied with the course, and, more importantly, they agreed that MATH 101 positively impacted their academic performance in MATH 201. However, the results of the last question in Section 1 indicate that the content delivery may not be engaging for some students. To address this issue, in the second edition of MATH 101, we will integrate game-designed activities into each virtual learning module to make the learning experience more interactive and enjoyable. It is well known that gamification [21] helps students stay focused and motivated, thus achieving better learning outcomes. In conclusion, Section 1 of the satisfaction survey revealed that students were satisfied with MATH 101 as they found it easy to use and effective.

Section 2 - Quality: This section evaluates students' perception of the course organization, quality of educational resources, feedback provided, assessment, and effectiveness of content delivery. Figure 9 summarizes the questions included in this part of the survey and the results obtained. Again, all the items in this section obtained a score above or equal to 75%, except for the last question. According to these results, the educational resources of MATH 101, including videos and exercises, are helpful for students in their learning process. In addition, the course content seems well-organized and accessible for most students. However, the result of the last question revealed that the feedback provided to students could be improved. In every course, feedback is vital because it helps students identify their strengths and weaknesses and consequently achieve better results [22]. In the second edition of MATH 101, additional practice exercises with detailed solutions will be incorporated into each virtual learning module so students can easily detect and learn from their mistakes. Overall, the findings from Section 2 of the satisfaction survey show that students were satisfied with the quality of MATH 101, but an additional effort in providing feedback is required.

Section 3 - Course Interface: Besides the quality of the educational resources, the design and accessibility of the course interface also play an essential role in the student's level of engagement and the effectiveness of their learning process. This section assesses the students' experience with the course interface, and the results are summarized in Figure 10. Note that all the items obtained a score above or equal to 75%. Therefore, for most students, the interface of MATH 101 is user-friendly, attractive, and has a straightforward navigation structure.

Section 4 - General Overview: To make a better assessment of the student's perception of the overall benefits obtained from taking MATH 101, we added a dichotomous and an open-ended question to the five-point Likert scale survey, namely:

- *"In summary, did you feel that MATH 101 was helpful for you?"* and
- *"Do you have any additional comments regarding your learning experience with MATH 101?"*

Dichotomous questions help assess the prevalence of a particular characteristic in the population under study. In this case, we confirmed what was expressed by the students in Section 1 of this survey since 98% said that MATH 101 was helpful for their academic success in subsequent mathematics courses.

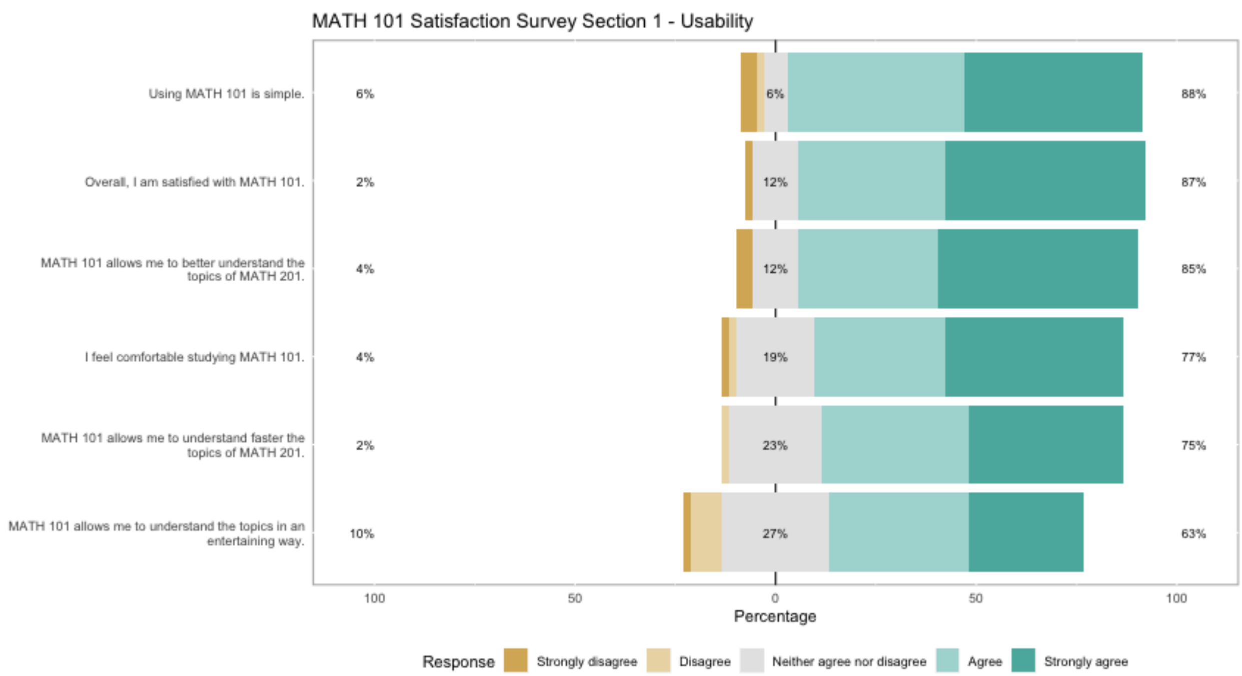


Figure 8 - Summary of the results from Section 1 of the Satisfaction Survey.

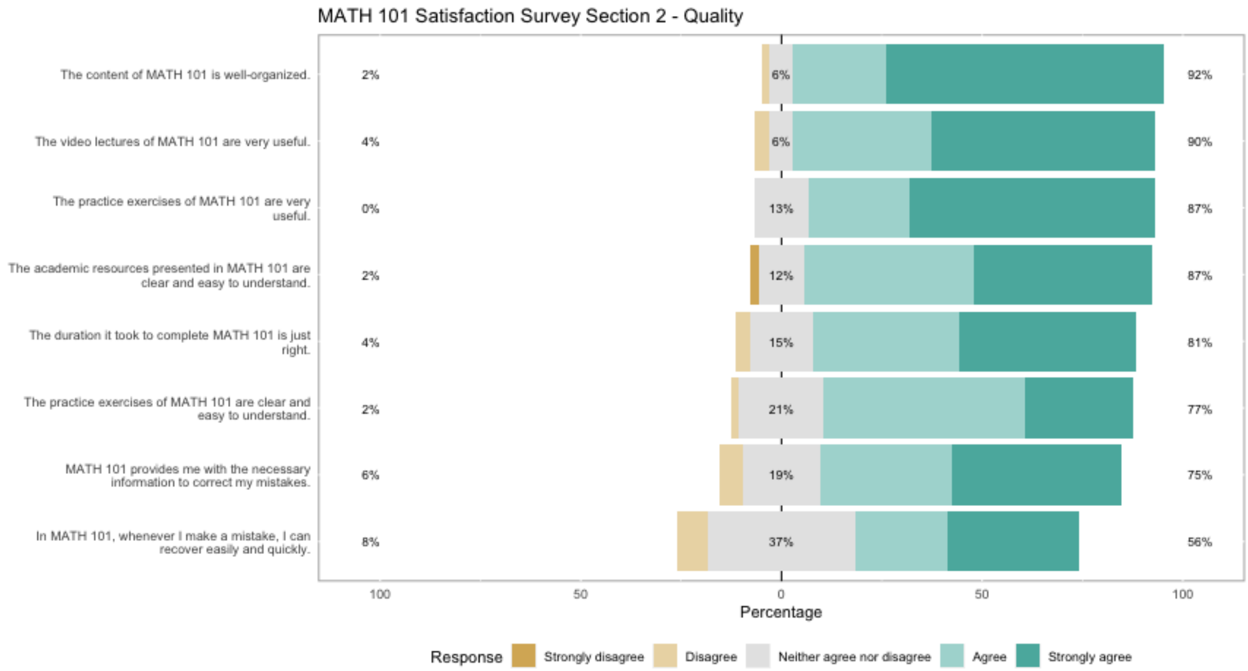


Figure 9 - Summary of the results from Section 2 of the Satisfaction Survey.

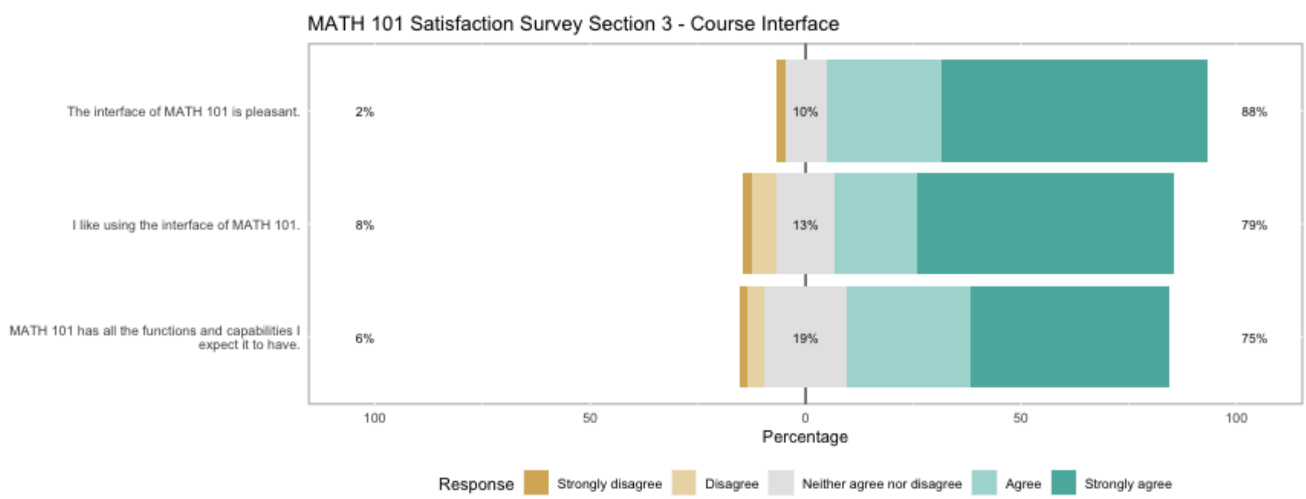


Figure 10 - Summary of the results from Section 3 of the Satisfaction Survey.

The open-ended question was added to the satisfaction survey to gather qualitative data and allow the students to provide us with more in-depth insights and feedback about MATH 101. The sentiment analysis [23] of the text containing all the answers to this question indicates that the comments received from the students had a predominantly positive tone. More precisely, the positive aspects outweigh the negatives and are more frequently mentioned in the students' answers. Among the positive points mentioned by the students, we can include the following:

- MATH 101 was useful in helping students to understand the topics of MATH 201.
- The explanations provided by the course materials are easy to understand.
- The student appreciated the implementation of MATH 101.
- The students stated that MATH 101 was very helpful in reinforcing their mathematics knowledge.

On the other hand, among the negative aspects expressed by the students, we can include the following:

- The need for more examples in specific modules of the course.
- The need for more information about the errors committed when solving the worksheets, i.e., insufficient feedback.

To summarize, the satisfaction survey results provided valuable insights into the students' perception and experience with MATH 101. Moreover, these outcomes will guide the new features to be included in future editions of this remedial course to enhance the student's learning experience.

4. Conclusions

The results of the first implementation of our virtual and adaptive remedial course for first-year engineering students at Galileo University are promising. The statistical analysis of the data collected by the course platform showed that MATH 101 accomplished its central objective of facilitating the transition from high school to university-level mathematics courses by reinforcing the students' concepts, operational skills, and problem-solving abilities that are pillars of those courses. Additionally, the satisfaction survey showed that most students found MATH 101 helpful as they recognized its impact on their academic performance in MATH 201. The course interface and the quality of the educational resources were also highly rated by the students. Hence, the quantitative and qualitative analysis of the data collected from the first run of MATH 101 suggests that it is suitable for remedying students with deficiencies in mathematics and aiming to pursue a degree in engineering. MATH 101 is an example of what an online course with a careful instructional design can accomplish in students.

Besides depicting the students' learning experience with MATH 101, the quantitative analysis of the data collected from the first implementation of MATH 101 also provided us with interesting results regarding the specific topics in which first-year engineering students present difficulties in mathematics. More precisely, most of our students' background in basic geometry and trigonometry is weak and needs to be reinforced in high school so that the students can have the opportunity to succeed in fields such as science and engineering. On the other hand, a common denominator found in arithmetic, algebra, and trigonometry is students' struggle when solving word problems and answering conceptual questions. Our numerical results evidence the necessity of building problem-solving skills in our students during primary and secondary education. Moreover, our analysis indicates that much effort in high school mathematics courses is put into solving operational exercises that neglect the concepts and theory in which mathematics is supported. Interestingly, the structure of MATH 101 revealed those topics that need improvement and the skills that urge to be promoted in our students. Exactly knowing what aspects need improvement, the path to success is laid out.

There are several alternatives to MATH 101; among them, ALEKS, WebAssign, and Khan Academy stand out in the market of tools for remedial mathematics courses. ALEKS is a web-based intelligent tutoring system based on Knowledge Space Theory designed to assess and teach students in areas such as mathematics, chemistry, statistics, and accounting [24]. It has been extensively studied in the literature [25] for its advantages and outcomes. More precisely, according to [25], most institutions that used ALEKS for remediation or as a supplement in mathematics courses had a higher learning rate and, thus, better performance in this area. Note that the statistical analysis of the data collected from the first implementation of MATH 101 is consistent with the latter observation. On the other hand, WebAssign is a versatile, web-based homework service that offers expanded learning opportunities to students [26]. Like ALEKS, WebAssign provides different benefits for students and teachers, especially in the design of learning activities [27]. Although it currently has more activity design options than MATH 101, WebAssign is not a remedial course but an aid in implementing this type of course. Finally, it is worth mentioning Khan Academy, a free educational platform including multiple subjects using adaptive learning techniques, that has shown to be excellent as support material in remedial mathematics courses, as stated in [28]. Once again, our results coincide with this remark and show that adaptive learning techniques are not only suitable for designing supplementary material for remedial mathematics courses but also for implementing a complete course, as in the case of MATH 101.

Even though the overall results of MATH 101 are positive, there are areas of improvement that will be addressed in future versions of this course. As identified by the satisfaction survey, such areas include the feedback provided to the students and the incorporation of more engaging educational activities. On the other hand, ongoing advances in Artificial Intelligence (AI) support the creation of more personalized and effective learning experiences for each student. Thus, incorporating AI techniques into MATH 101 is a part of our future work. With these refinements, we will continue providing an effective tool for Latin American students to improve their mathematical skills and succeed in their university studies.

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6. References

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