



Artificial Intelligence in Personalized Learning in Mathematics

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Abstract. For several years now, Artificial Intelligence (AI) has revolutionized the education sector as it helps teachers create an effective mastery learning environment supported by personalized learning, which motivates students to reach their full potential in the classroom. By offering each student individualized tutoring, artificial intelligence helps close the learning gap described in Benjamin Bloom's Problem 2 Sigma. This study aims to understand how Classera can solve Bloom's 2 sigma problem in learning mathematics. To achieve the purpose of the study, mixed-approach research instruments are used between selected students and high school mathematics teachers. Data were obtained from surveys and interviews with study participants. The results of the data analysis indicate an improvement in students' academic performance. The findings will be used to provide recommendations for students to master each level and progress in their learning journey.

Keywords: learning factors, personalized tutoring, Benjamin Bloom, education.

1 Introduction

Benjamin Bloom, around 1984 observed that students who learned through individual tutoring performed 2 sigma's better than students who received instruction in the traditional school setting (usually the teacher and some students) (Bloom, 1984). This educational phenomenon called Bloom's 2 sigma's is an effective way to optimize student learning. While one-on-one personalized learning is significant, Bloom also understood that providing a private tutor for each student is a problem, especially when costs are considered (Lozada, 2019). The advances and current maturity of learning technologies have made many possibilities appear to solve the problem of personalized learning.

The AI-powered tutoring system is presented as an effective solution to solve Bloom's 2 Sigma problem through personalized and contextualized learning that employs one-on-one tutoring. S Among the works found on AI-driven tutoring systems, the following stand out: "Advance in Intelligent Tutoring Systems" (Nkambou, Mizoguchi, & Bourdeau, 2010), "Artificial Intelligence in Intelligent Tutoring Robots: A Systematic Review and Design Guidelines" (Yang & Zhang, 2019) and "Evolution and Trends in Intelligent Tutoring Systems Research: A Multidisciplinary and Scient metric View" (Guo, y otros, 2021), however, the scope of research on the subject is still small. Apart from what he gave, there has been a dearth of studies that analyze the effectiveness of the use of Classera, the integrated application of AI, for personalized learning. In addition, little attention has been paid to the analysis of the use of this application for personalized learning in mathematics. The goal of this research paper is to try

to fill those gaps. We want to understand how an AI-powered tutor like Classera can solve Bloom's 2 sigma problem.

How Classera allows personalized learning based on the strengths, weaknesses, and preferences of the student, that is, considering their innate characteristics, has been investigated. To examine how personalized learning leads to smart learning, selected mid-section students and teachers were surveyed and interviewed at one of Ecuador's schools.

Artificial Intelligence is revolutionizing education globally. It can ensure efficiency, the development of personalized learning and streamline administrative tasks, this allows both teachers and students to better play their roles in the educational process. As proof of this, some of the applications that use AI in the academic field can be mentioned: a) Thinkster Math (Shen, Chen, Grey, & Su, 2021), is a personalized learning application that enables better learning of mathematics, b) Alexa (Ramadan, Farah, & El-Essrawi, 2021), voice-enabled help in the teaching and learning program, c) Apple Siri (Haryanto & Ali, 2019), help in time management of tests or questionnaires, d) ELSA speak (da-Silva-Souza & de-Mesquita-Neto, 2022), is an application that uses AI to learn English words easily, e) DataBot (Osipyan, Edwards, & Cheok, 2022), is an AI-powered virtual assistant that provides images, information, and multimedia presentations based on the topic of interest, f) Squigl (Kit, Yuin-Y, Zulkifli, & Nie, 2023), is an AI-powered content creation platform that transforms spoken words and text into highly effective animated videos.

As the powerful educational tool that it is, Artificial Intelligence has begun to alter the learning process. "With ... Artificial intelligence (AI) capabilities, new learning-oriented solutions are developed and tested globally" (Saville & Buttery, 2023), quoted in (Jaiswal & Arun, 2021; Mazón-Fierro, 2022).

Artificial Intelligence helps educators create an effective learning environment supported by one-to-one (student-teacher) interaction, which motivates students to reach their full potential in classrooms. By offering each student one-on-one tutoring, AI helps bridge the learning gap expressed in Bloom's 2 sigma problem. It has also debunked the misguided and outdated notion of categorizing students into high and low-achievement groups in learning. By individualizing the environment in which learning sessions take place according to the learning styles and characteristics of the students (age, cognitive characteristics, previous knowledge, preferences, etc.), the AI-powered personalized domain learning system or one-to-one tutoring system helps students placed in the category of low learning performance to perform better.

According to (Aldosari, 2020), by analyzing the history of previous learning and identifying its weaknesses and strengths, Artificial Intelligence solutions allow for designing personalized courses that are the most suitable for the improvement of a student. AI-based learning tools also allow tracking of a student's learning progress, this allows AI tools to be tailored to each student's knowledge level, learning speed, preferences, and expected goals. In this way, students are supported on their way to mastering learning (Ganja, 2017; Granda, 2022).

Classera is an effective integrated Artificial Intelligence application that aids in personalized learning. Classera's engine automatically recognizes a student's weaknesses and allows them to develop their academic strengths through content review and execution of specific activities recommended for each student. In addition, Classera can suggest content required by students according to their knowledge of concepts. This research article focuses on the use of Classera for personalized learning of students from the secondary section in the subject of mathematics.

2 Methodology

This section presents the research questions posed by the researchers to achieve the objective of this research, as well as the research participants, the instruments used to collect the data, and the procedures followed to process the data in search of objective answers to the research questions. Likewise, the statistical process that was carried out from the comparison of the qualifications of two groups of students (58 in total), one control and another experimental that participated in the study, the students of the experimental group used Classera during a school year to determine the level of improvement that

occurred with the use of this application. The planning phase of the experiment carried out is also presented.

1.1 Research Questions

This study aims to answer the following research questions:

1. What is the effectiveness of using Classera, the integrated AI application, for personalized learning in mathematics?
2. How would personalized learning help accommodate learning material to meet students' needs?
3. Is there a statistically significant difference between the scores obtained by the students participating in the study in the test that measures their performance after using Classera compared to the students who did not use the app?

1.2 Participants

Participants involved in this study include a select group of high school students and math teachers.

In the field test of the study participated 58 students in their third year of Baccalaureate, 32 of which were male, the experiment used a control group (29 subjects) and an experimental group (29 subjects), being that the control group was composed of 29 students of the previous academic cycle and the experimental group was integrated by 29 students of the academic cycle in which Classera was used as support of the sessions of mathematics learning, the field study was carried out in an Educational Unit of the city of Riobamba, Ecuador.

1.3 Data collection instruments

To achieve the objectives of the study, mixed-approach research tools are used. The first research instrument is to survey students and teachers of mathematics in the secondary section. The goal of the survey is to evaluate the effectiveness of Classera in improving instruction and personalized learning in mathematics. The second instrument is to interview math teachers and students who use this application. The interview is used to directly understand the effectiveness of this application.

As a third data collection instrument, the test has been used. The test taken by the students of the experimental group was carried out in the first instance by their teacher and reviewed by a group of their colleagues, who specialized in mathematics. In addition, the team of researchers requested the help of two secondary mathematics teachers and two external teachers specialized in evaluation for the revision of this instrument, this was done so that this instrument has the same level of complexity and adequately covers the topics that were treated in the previous cycle with traditional tools. The applied assessment consists of 32 questions divided between multiple choice questions of a single answer, filling holes, matching and each correct answer added with one point to the final grade obtained by the student. After learning with Classera, this assessment was applied. The main objective of these tests was to examine the understanding and abstraction of knowledge that allows them to perform the tasks exercised with the use of the AI-based application proposed by this study.

1.4 Data collection procedure

The procedures used for data collection in this study consist of the following:

Teachers were asked to complete a survey containing a set of questionnaires identifying the effective use of Classera. Students were asked to complete a survey based on their personalized learning experience from Classera. The survey was conducted after a year of using Classera for better results. Interviews with math teachers and students helped to understand their opinion, as open-ended questions are used.

1.5 Planning and Justification of the Executed Experiment

The proposed study has as one of its objectives the study of the effect of AI-based digital didactic resources as material in a secondary-level mathematics course. For them, an interview was held with the mathematics teacher of the course before the development of the use of Classera in the development of the classes, who, based on his teaching experience, was able to tell the researchers that his students of previous cycles were not very motivated compared to the traditional way in which classes are taught and, Perhaps because of the complexity and abstraction of the contents of the subject, they did not

understand first-hand, the contents that were presented in this subject specifically. After the conversation held, the professor expressed his interest in the proposed research and committed his help to review these contents during a school period with the help of a tool that uses Artificial Intelligence to in the first instance, awaken and stimulate the interest of his students while maintaining their attention, to improve and facilitate the learning of the aforementioned contents.

After the interview, it was decided that the experiment would employ a control group and an experimental group. The data of the results of the control group would be provided by the teacher based on the learning results obtained by the students who took the mathematics subject the previous year, a period in which traditional classroom resources (textbook, web pages, and static slides) were used.

On the other hand, the contrast scores were obtained from the learning results obtained by the students of the experimental group, who took the subject of mathematics in the academic period in which the research was carried out, with the use of Classera, an application that was used as a support for the teaching of mathematics contents.

It is worth mentioning that, without being the same evaluations, the students of both groups were evaluated on the same topics (those determined by the national macro curriculum for the level), with the same complexity in both cases, to obtain objective results. In addition, none of the resources presented to the students of the experimental group contained the exact items of the evaluation that was carried out after the use of Classera, in the design of the evaluation it was also considered that to record their answers, each student should reach their conclusions from the exploration, the exercise, and deduction that underpinned the design of the classes in which they used Classera, which were based on inquiry learning.

The researchers also consider that the difference between the results of both groups of students will represent the effect (benefit) that this AI-based application has on the learning of the contents that were not fully assimilated in the previous academic period. The application of the evaluations to the control and experimental groups was statistically analyzed before the discussion of results and the obtaining of conclusions. The experiment consisted of the execution of 4 phases, as shown in Table 1.

Table 1: Experimental design executed

| Phase of the experiment | Methods |
|--|---|
| Control evaluation | At the end of the school term, each student in the control group individually had to complete a written evaluation that measured their learning outcomes concerning the topics of the mathematics subject according to their level. |
| Training of working couples and use of KARMLS. | The students participating in the study were instructed in the classroom by their teacher on the topics on which they would practice with the Classera application. After this, they were randomly gathered into 13 groups of 2 children (and a group of three children) to form work teams, each group, with the teaching guidance was asked to use the Classera application, with role switching for 8 minutes for each student in each class session for which the use of the app was planned. always follow the instructions provided by the teacher. Also, during the first learning sessions, the group of researchers was present to support any situation that merits and until the young participants learn the management of the application, which is very intuitive so the participation of the researchers was almost null being, like the teacher, mere spectators at the time of the execution of the experiment, indicating to the students only when to change roles (when they were spectators and when they used the application). |
| Evaluation of the experimental group | At the end of the academic period, each student in the experimental group (individually) completed a written assessment with the same difficulty and on the same topics as that given by the students in the control group. |
| Analysis of results | We proceeded to statistically contrast the results collected in the evaluation of |

both groups of students to verify whether or not there is an improvement in the performance of the study participants after using the Classera application (experimental group) and if this difference is statistically significant.

Source: The authors

To answer the research question: Is there a statistically significant difference between the scores obtained by the students participating in the study in the test that measures their performance after using Classera concerning the students who did not use the application?, the statistical analysis of the results obtained in an evaluation by the control group versus those obtained by the experimental group has been carried out, These results will be examined and tested from the findings of the field experiment that has been executed.

3 Discussion and results

The integrated application of artificial intelligence Classera is an effective application that helps in personalized learning and improves learning to the extent that their skills, strengths, deficiencies, prior knowledge, and preferences are properly considered (Luna-Encalada, et al., 2021;Paucar-león,2022).

One-on-one tutoring helps students improve their metacognitive processes and facilitates knowledge acquisition. It also provides benefits for how the actors of the educational process interact since in this modality it is possible to both exchange individualized and immediate comments and analysis of the student's progress live (Cabezas-Heredia, Molina-Granja, Delgado-Altamirano, & Ruiz-Duarte, 2021). The tools of this engaging platform allow educators and students of subjects with abstract and often complex content, such as mathematics to create, graph, solve, and animate mathematical problems easily, all with their handwriting with the use of an interactive whiteboard. The app helps teachers create digital learning materials that are dynamic and provide new learning experiences that are perceived as engaging and motivating by students. On the student's side, the app helps to understand math concepts more easily (Molina-Granja, y otros, 2022).

It is worth mentioning that Classera's educational partner, FluidMath, is also a fun application to practice automaticity, fluency, and arithmetic in a gamified environment. Collaborative problem-solving in this tool helps students explore and understand math concepts. The collaborative whiteboard can be used in synchronous online teaching and cooperative learning. With the help of this app and one-on-one class sessions, teachers can provide differentiated instructions and problem-solve by analyzing student progress. The presence of a virtual Math keyboard makes it easy to input mathematical notation with laptop keyboards. Thus, FluidMath is an effective application integrated into Classera that allows you to present a dynamic, attractive, and interactive environment.

This section will answer research questions and discuss the results of data analysis. With the use of Classera, there has been considerable academic growth in the students participating in the study.

Fig. 1. is a graph based on the survey and interviews conducted on the growth of learners and their learning time per day using Classera. When analyzing the observation reports of the surveys, the graph shows that the academic growth of each student has increased by approximately 48.28% compared to the traditional method of learning. It can also be observed that student participation in learning time has increased by 30%.

Therefore, personalized learning has helped learners in their learning journey. The self-assessment system has allowed them to identify their weaknesses and improve their mathematical skills. Surveys and interviews among participants show that 80% of students and 90% of teachers have a positive opinion about the effectiveness of using Classera.

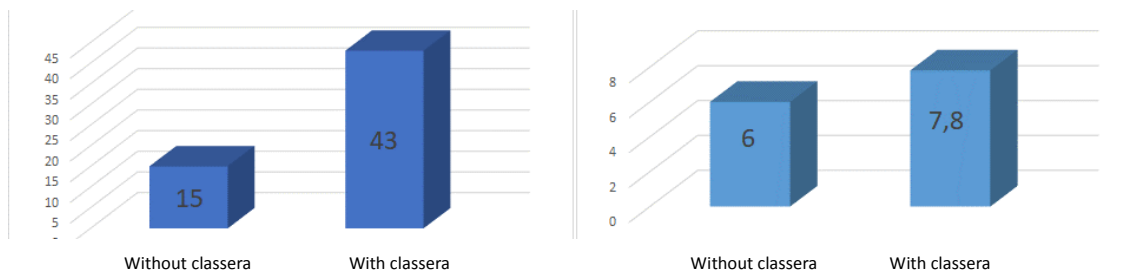


Fig. 1: Average student growth / Average learning time per day
Source: The authors

During the learning process, the teacher analyzed the results obtained by the students and provided differentiated learning materials according to each need. Based on the level of knowledge of the students, Classera, an application with integrated AI allows this creation and distribution to be done easily.

The students interviewed explained how personalized learning with the help of the AI Classera application helped them understand abstract mathematical concepts and develop their mathematical skills. In addition, personalized recommendations and suggestions allowed them to understand and analyze the specifications and results of their math course in a better way.

Since each student was given the freedom to learn at their own pace and experiment with the Classera application with AI even in the absence of their teacher it already worked at any time taking advantage of the ubiquity of Internet applications. This internship created an interesting, motivating, and insightful student experience. One-on-one tutoring allowed students to master each level and progress in their learning journey.

As for the field test, the experiment produced 58 ratings (29 from the control group and 29 from the experimental group) being 32 points the maximum qualification that could be achieved, from these scores the t-students test was performed for independent samples between the qualifications obtained by the students participating in the study divided into the two groups already mentioned. To verify the difference after using the application with AI, the variable evaluated is the difference between the means of the grades obtained by the students of both groups. The results of this test are shown in Table 2.

Table 2: Grades obtained (Out of 32 points)

| Subject N° | Control group | Experimental group | Subject N° | Control group | Experimental group |
|------------|---------------|--------------------|------------|---------------|--------------------|
| 1 | 18 | 25 | 16 | 25 | 31 |
| 2 | 18 | 30 | 17 | 26 | 31 |
| 3 | 19 | 29 | 18 | 26 | 32 |
| 4 | 19 | 30 | 19 | 27 | 30 |
| 5 | 20 | 28 | 20 | 27 | 29 |
| 6 | 20 | 29 | 21 | 28 | 29 |
| 7 | 21 | 31 | 22 | 28 | 32 |
| 8 | 21 | 31 | 23 | 29 | 28 |
| 9 | 22 | 33 | 24 | 29 | 28 |
| 10 | 22 | 29 | 25 | 30 | 31 |
| 11 | 23 | 27 | 26 | 30 | 30 |
| 12 | 23 | 32 | 27 | 31 | 28 |
| 13 | 24 | 33 | 28 | 31 | 31 |
| 14 | 24 | 31 | 29 | 32 | 33 |
| 15 | 25 | 30 | | | |

Source: The authors

Before carrying out the t-student test, the normality test of the samples corresponding to the qualification obtained by the study participants separated into the control and experimental groups has been executed. For this, the Realstats Excel plugin has been used to perform the Shapiro Wilk normality test, the results of this test are shown below:

Control group

Results:
n = 29
Avergae = 24.758620689655178
Standar deviation = 4.264933196711736
W = 0.9499073027775623
Threshold (p=0.01) = 0.8980000019073486 --> HO accepted
Threshold (p=0.05) = 0.925999990463257 --> HO accepted
Threshold (p=0.10) = 0.9369999766349792 --> HO accepted

Conclusion: There is no statistical evidence that indicates that the scores obtained by the control group are not normal.

Experimental group

Results:
n = 29
mean = 30.03448275862069
Standard deviation = 1.898923729392326
W = 0.9526917639377763
Threshold (p=0.01) = 0.8980000019073486 --> HO accepted
Threshold (p=0.05) = 0.925999990463257 --> HO accepted
Threshold (p=0.10) = 0.9369999766349792 --> HO accepted

Conclusion: There is no statistical evidence that indicates that the qualifications obtained by the experimental group are not normal.

Two-sample t-test After having verified the normality of the samples and since it was a set of fewer than 30 subjects, it was determined that the probability distribution that would be used for the study is the t-student test for independent samples, which will determine if there is a statistically significant difference between the averages of the grades obtained by the students participating in the study by comparing the results obtained by the youngsters separated in the control and experimental groups, said the statistical test will objectively determine if said difference is due to the use of the Classera application with AI or if such a difference is due to chance. The results of the t-student test are shown in Table 3.

Table 3: T-student test for independent samples assuming equal variances

| Two-sample t-test assuming equal variances | Grupo de control | Grupo experimental |
|--|------------------|--------------------|
| Media | 24,75862069 | 30,03448276 |
| Variance | 18,18965517 | 3,60591133 |
| Observations | 29 | 29 |
| pooled variance | 10,89778325 | |
| Hypothesized difference of means | 0 | |
| Degrees of freedom | 56 | |
| Statistical t | -6,085669333 | |
| P(T<=t) one-tailed | 5,5122E-08 | |
| Critical value of t (one-tailed) | 1,672522303 | |
| P(T<=t) two tails | 1,10244E-07 | |
| Critical value of t (two tails) | 2,003240719 | |

Source: The authors.

From the data obtained in the statistical test, with the calculated t value ($t = -6.0857$), with the one-tailed critical t value for $n=29$ ($t\text{-crit} = 1.6725$), and with the p-value for one tail ($p\text{-value} = 5.5122E-08$), the null hypothesis is rejected and it is concluded that the difference between the means obtained by the control group (24.76) and by the experimental group (30.03) is statistically significant and that the observed improvement is due to the use of the Classera application with AI and that said difference is not due to chance.

4 Conclusions

AI-powered tutoring systems can help students understand concepts more easily and develop their learning skills (metacognition). With the support of tools based on artificial intelligence, educators can help reduce the gap for their students, whether they have been considered in the high-performing group or not, this is undoubtedly perceived as a better educational experience.

The findings of this study are limited to the activities of participation, exploration, and evaluation in the learning process. The use of an AI-powered personalized tutoring system that focuses on fast-paced activities has not been explored in this study. Therefore, future research is required on how AI-based educational tools serve to guide students to apply the knowledge acquired in real-life contexts. Limiting the study to Classera does not negate the use of other assorted educational applications in effective personalized learning of mathematics.

Furthermore, focusing on learning mathematics does not imply that AI educational tools can only be used to provide individual tutoring for learning mathematics and not for other subjects.

It is important to consider that AI is relevant not only for current educational programs but also for those of the future. Since the goal of educational programs is to prepare students for a future where artificial intelligence advances and supports the development of human activities, students must acquire AI-related knowledge and skills.

The statistical analysis of the data obtained in the field experiment allowed us to determine that there is a statistically significant difference between the scores obtained by the students participating in the study in the test that measures their performance after using Classera with AI compared to the scores of the students who traditionally received their mathematics classes and that said difference was produced thanks to the use of the application.

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