




## **Analytics and Usage Gaps of Digital Platforms for Mathematics Education in Uruguay<sup>1</sup>**

### **Analíticas y Brecha de Uso de Plataformas Digitales para la Educación Matemática en Uruguay**

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**How to cite:** Rodríguez, E., Bentancor, G. y Solari, M. (2025). Analytics and Usage Gaps of Digital Platforms for Mathematics Education in Uruguay. *Revista Electrónica de Investigación Educativa*, 27. <https://doi.org/10.24320/redie.2025.27.of.6438>

#### **Abstract**

Antecedent. Uruguay is known for its early and sustained incorporation of programs that foster the use of digital resources in public education. The country selected the mathematics education platform Bettermarks to support the educational process of students. Objective. This research analyses the data on access and usage of the digital platform for mathematics education among secondary school students both before and during the COVID-19 pandemic. Methodology. A descriptive and inferential statistical approach was used to analyze historical data on individual student interaction with the online learning activities. Results. The findings revealed that, from 2017 to 2020, there was a notable increase in the coverage rate, rising from 22% to 49%. Similarly, the

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<sup>1</sup> Proyecto financiado por: Fondo Sectorial de Educación, Fundación CEIBAL y Agencia Nacional de Investigación e Innovación (ANII) – Uruguay (FSED\_2\_2020\_1\_163598)



activities completed by active users experienced an upward trend in 2020. The platform provided greater coverage; however, when analyzing the activity rate across the years, no significant differences were observed. Originality. The analysis tested several hypotheses to elucidate the heterogeneities in the access and interaction modalities among students using the digital resources. Statistically significant differences were observed in terms of coverage and activities performed by students based on different factors.

**Keywords:** COVID-19; Secondary School Mathematics; Mathematic Education.

## **Resumen**

Antecedente. Uruguay se caracteriza por la incorporación temprana y sostenida de programas que fomentan el uso de recursos digitales en la educación pública. El país seleccionó la plataforma de educación matemática Bettermarks para apoyar el proceso educativo de los estudiantes. Objetivo. Esta investigación analiza los datos sobre el acceso y uso de la plataforma digital para la educación matemática entre estudiantes de secundaria antes y durante la pandemia de COVID-19. Metodología. Se utilizó un enfoque estadístico descriptivo e inferencial para analizar datos históricos sobre la interacción individual de los estudiantes con las actividades de aprendizaje en línea. Resultados. Los hallazgos revelaron que, de 2017 a 2020, hubo un aumento notable en la tasa de cobertura, pasando del 22% al 49%. Asimismo, las actividades realizadas por los usuarios activos experimentaron una tendencia ascendente en 2020. La plataforma brindó mayor cobertura; sin embargo, al analizar la tasa de actividad a lo largo de los años no se observaron diferencias significativas. Originalidad. El análisis probó varias hipótesis para dilucidar las heterogeneidades en las modalidades de acceso e interacción entre los estudiantes que utilizan los recursos digitales. Se observaron diferencias

estadísticamente significativas en cuanto a cobertura y actividades realizadas por los estudiantes en función de diferentes factores.

**Palabras clave:** COVID-19, Matemáticas Escuela Secundaria, Educación Matemática.

## **Introduction**

In Latin America, Uruguay has positioned itself prominently, when compared internationally, thanks to its sustained development of public policies aimed at universalizing access to digital technologies and providing free internet coverage for teachers, students, households, and educational institutions since 2007 (Mateu et al., 2018; Pittaluga & Rivoir, 2012).

CEIBAL pioneered the implementation of large-scale policies for the incorporation of Information and Communication Technology (ICT) devices and resources in the region (Lugo & Ithurburu, 2019). This widespread access to ICT in education has facilitated the creation of learning environments and classrooms with a significant presence of devices, resources, tools, and educational platforms (Ibarra et al., 2017; Ripani & Muñoz, 2020).

Among the most outstanding initiatives that embrace the use of free digital tools for the educational community, the content and resources platform for education and learning, CREA; the digital library; and the platforms for mathematics teaching, MATIFIC for primary education and the Adaptive Mathematics Platform (PAM), for both primary and secondary education, should be highlighted. CEIBAL's reports confirm a progressive accumulation in the offer of digital resources in recent years, along with a wide array of teacher training programs and projects for technological innovation that articulate the widespread access to ICT from a perspective of social equity (Díaz et al., 2022).

In this regard, a technical report from CEIBAL, prepared in December 2020, revealed that, in that year, 100% of primary and secondary education institutions had connectivity

with internet access and that CREA, the virtual learning environment platform, had reached 320,000 students and teachers from all subsystems. Additionally, in the same year, 130,000 students accessed and utilized the digital learning resources of PAM. Within this general context of digitalization of educational data, CEIBAL has made progress in the process of professionalizing its data center and, in 2022, it established an observatory which includes a national catalogue of open data containing information on the educational platforms offered by CEIBAL to students and teachers between 2019 and 2022 (CEIBAL, 2022).

Nevertheless, and despite all the efforts made in the past 17 years in terms of training policies, universalization and availability of usage data and educational platforms, the pedagogical use of ICT was still in its initial stages in the years preceding the pandemic, as reported by Cobo and Montaldo (2018). It is likely one of the most significant challenges encountered by the emergency remote education system that was implemented upon the arrival of COVID-19 (CEPAL, 2020; Vaillant et al., 2022).

The research, whose results are presented in this report, was conducted within the national context of universal and free access to digital technologies in the years preceding the arrival of COVID-19 in the country, with progress made in narrowing access gaps, yet simultaneously facing pending challenges regarding the pedagogical use of these resources in classrooms.

The overall objective of this project is to study the usage analytics of the PAM platform with the aim of providing evidence on the relevance of digital data for the design of proposals on pedagogical interventions and for the customization of learning approaches for students.

Through the development of a data mining methodology that leverages historical usage records of PAM between the years 2017 and 2020, this work analyses student behavior

patterns and establishes relationships among the variables that characterize the technological context of using digital tools for learning mathematics. This methodology entails the development of a process for collecting, systematizing and analyzing data on the student's individual interaction with PAM's online learning activities. Moreover, the present report provides insights into the different profiles of access and interaction of students with the digital resources offered by PAM through a comparative method of results based on the context of compulsory education prior to the interruption of face-to-face education (March 2020) and the various social, demographic, and educational factors obtained from CEIBAL's databases.

### **Digital Platform for Mathematics Education in Uruguay**

In Uruguay, the Bettermarks platform is referred to as the Adaptive Mathematics Platform (PAM for its Spanish acronym). Since 2013, this platform has been made available to students and teachers in public lower secondary education. A German company that specializes in the design and development of educational software created the platform's tools, and they have been adopted in various educational systems, both regionally and globally (Spitzer & Moeller, 2022; Stein, 2015). PAM provides over 100,000 exercises and other resources to help teachers to adapt their strategies to the pace and diversity of their students' learning processes. In addition, it provides information on the frequency of access, type of activities, number of completed series, students' progress records and data from assessments teachers conduct to evaluate students' performance in the mathematics virtual classroom.

As detailed in the subsequent sections, this results report presents a set of PAM access variables and login indicators, variables of students' digital interactions with PAM, and

information on the social and demographic context of both the students and the educational institutions.

The central hypothesis of the adopted empirical approach is that the impact of partial or total closure of schools and the transition from ICT-supported face-to-face teaching to virtual or blended education, resulting from the closure of educational institutions, led to heterogeneities and different intensities of usage of digital resources. These heterogeneities are observed in the PAM access variables and the interactive processes between students and the platform.

The structure of the article was organized by creating two blocks of questions based on the empirical variables extracted from the digital databases of PAM users.

Initially, a first set of variables of access to PAM was identified and different indicators of use were created: login days, coverage, activation, access frequency and period (during or prior to the pandemic).

The questions that guided this empirical analysis in its initial phase are the following:

- What were the patterns of student behavior and access to the PAM platform before and during the first year of the COVID-19 pandemic?
- Are there differences in terms of PAM coverage, activation, and usage intensity according to the grade levels students were in the years before and during the COVID-19 pandemic?
- Are there statistically significant differences in the utilization of PAM based on gender, school size, region, year, and grade level of lower secondary education students?

Subsequently, the analytical approach was oriented towards the study of the variables related to student interaction with the educational software's own resources (activity logs,

completed series, stars and medals obtained by the students). The new block of questions that guided this second phase of analysis is as follows:

- What social factors account for the heterogeneities in usage in the different modes of interaction between students and PAM?
- Are there statistically significant differences in students' modes of interaction with the resources offered by PAM based on gender, school size, region, year, and grade level of the educational cycle?

### **Related Work**

The review of international literature, specifically on the use of digital technology in mathematics education, presents compelling evidence regarding the advantages it offers for teaching practice (Hillmayr et al., 2020; Olsher & Thurm, 2021). Several researchers (Ball et al., 2018; Thurm & Barzel, 2022; Villamizar et al., 2020) highlight the efficacy of digital technology in providing multiple forms of representation of mathematical objects; supporting and strengthening experimental work and modelling real-world scenarios; fostering comprehension, meaningfulness, and interpretation of intra-mathematical and extra-mathematical problems; and facilitating the validation of results. Furthermore, the International Computer and Information Literacy Study 2018 (ICILS), involving eighth-grade teachers from twelve countries, found strong adherence to the use of digital technologies for teaching. Eighty-seven per cent of the participating teachers believed that digital tools contribute to students' personalized learning, 91% agreed that these technologies help cultivate students' interest in learning and 78% recognized that they enhance collaborative work (Fraillon et al., 2019).

Nevertheless, digital technology relies on teachers' pedagogical knowledge and an appropriate didactic implementation to fully leverage its transformative potential (Molina-

Toro et al., 2019; Thurm & Barzel, 2022) and mitigate its negative effects (Fraillon et al., 2019).

Despite the evident benefits documented in the literature and the positive views expressed by teachers, the integration of digital tools in mathematics education is still in its initial stages, and their potential to transform pedagogical practices and the construction of mathematical knowledge is underutilised (Vaillant et al., 2019). Moreover, many teachers tend to focus on promoting technological skills rather than effectively combining technology with pedagogy to design student-centered pedagogical approaches that foster personalized and autonomous learning (Chiu & Churchill, 2015; Rakes et al., 2020).

Research conducted internationally by Area-Moreira et al. (2016) and in Uruguay by Rodriguez and Grilli (2019) revealed that, despite the widespread adoption of digital technology in classrooms driven by the inclusion of technology in teaching policies, its use remains predominantly instrumental, focused on algorithmic exercises and basic utilization for visualization and result verification, with no significant changes towards employing digital tools in a pedagogically meaningful manner or adopting student-centered approaches.

Several researchers (Ran et al, 2021) indicate that increased use of educational platforms, particularly the Bettermarks platform (Spitzer & Musslick, 2021), can lead to an improved performance of secondary school students. Such improvements may also be enhanced by the incentives offered by teachers (Spitzer & Musslick, 2021) and the customisation of learning experiences according to students' needs (Cullen et al., 2020).

### **Previous Studies on Bettermaks**



There is prior educational research on Bettermarks, specifically within the regional education systems of Germany. A noteworthy research project, cited by the promoter of the platform, carried out a systematic comparison of usage cases (Stein, 2015). According to the study, Bettermarks stands out as a tool that outperforms others in terms of performance and adaptability in the various dimensions of mathematical problem-solving.

Subsequent field studies on Bettermarks have examined its impact on learning outcomes and the potential to predict the performance of students who use the platform. Performance prediction using a large volume of data is one of the key features for the platform's adaptability, as well as for providing feedback to students and teachers. One of the studies combines a knowledge representation graph with learning activities and objectives (Stapel et al., 2016). Moreover, this graph is combined with a robust prediction system that is based on students' interactions with the system, demonstrating enhanced accuracy in classification compared to previous systems. The platform's predictive potential was also addressed in a more recent study (Spitzer & Moeller, 2022). This field study, conducted in the Netherlands, highlights the significance of fraction learning as one of the essential mathematical skills, which serves as a predictor of performance in algebra.

During the COVID-19 pandemic, there were studies conducted that identified remote teaching practices during the period of confinement. One such study surveyed teachers from Germany, Belgium, and the Netherlands (Drijvers et al., 2021). Findings revealed an increase in the use of videoconferencing tools, but a decrease in the use of specific tools for teaching mathematics. Differences were observed between the three countries due to the digital tools made available and the educational policies within each educational system. While the usage of mathematics exercise platforms (including

Bettermarks) decreased in Belgium and the Netherlands, it experienced a slight increase in Germany. Another study carried out in Germany in 2020 found that students who utilized the online exercise platform showed an improvement in their academic performance (Spitzer & Musslick, 2021). This improved performance was more significant among students with lower academic performances, demonstrating the platform's potential to bridge the gap.

## **Methodology**

Since the rise of big data, the field of educational sciences, particularly applied educational research, has been facing the challenge of systematizing and interpreting a vast array of usage records and digital data that students and teachers generate during their teaching and learning experiences in technological environments (Siemens, 2013; Suhirman et al., 2014).

Teixeira and Zapata-Ros (2021) suggest that the study of large volumes of educational data calls for a thorough observation of usage patterns and for an emerging methodological approach based on artificial intelligence and personalized massive data analytics. Likewise, the Society for Learning Analytics Research defines the educational analytics approach as (SoLAR, 2011) the measurement, collection, and analysis of large databases of student, teacher and context data aiming to comprehend and optimize the learning processes and the environments in which it takes place (Siemens, 2013).

The study presented herein relies on the development of a data mining methodology based on the analysis of the historical records of PAM usage between the years 2017 and 2020. To establish relationships between the variables that characterize the technological context of using digital tools for mathematics learning, the behavioral patterns of the students were studied.

This approach made it possible to meet the following objectives:

- To analyze the analytics of the access to the PAM platform before and during the first year of the COVID-19 pandemic and to examine whether there are any correlations with the associated factors.
- To analyze the analytics concerning student interaction with the PAM platform before and during the first year of the COVID-19 pandemic and to identify heterogeneities regarding its use.
- To determine whether there are any correlations between the different interaction modalities and the associated factors.

The empirical method entailed the development of a process to collect, systematize and analyze historical data on individual student interaction with the online learning activities offered by PAM.

The empirical method of data mining analysis involved the development of a process of collecting, systematizing, and analyzing historical data on individual student interaction with PAM's online learning activities. Descriptive and inferential techniques were applied for classification, identification of patterns and outliers and clustering, as well as statistical tests for the analysis of observed differences, such as Student's t-test and ANOVA.

The first step was to access a database provided by CEIBAL that is composed of two fields: student ID (anonymized) and calendar year (2017, 2018, 2019 or 2020). This file, provided in Excel format, contains a record for each unique combination of the two fields. The database has a total of 156,331 records ('login events') from students who use PAM. Each student attends a school and is enrolled in a specific grade level, 7th, 8th, or 9th grade of lower secondary education. The database includes all PAM users for each grade level. Depending on the number of years that a student has attended a grade in the

specified period, they can have one, two or three records in the database. In summary, the database CEIBAL provided comprises 113,102 different students, 265 educational institutions providing compulsory basic education and documents 156,331 PAM login events during the selected timeframe (Table 1).

**Table 1**

*Description of PAM Login Events According to the Number of Schools and Grade Levels*

<b>Year</b>	<b>7<sup>th</sup></b>	<b>8<sup>th</sup></b>	<b>9<sup>th</sup></b>	<b>Logins</b>	<b>Centres</b>
<b>2017</b>	12971	9222	6784	28977	249
<b>2018</b>	11962	11193	7098	30253	248
<b>2019</b>	16526	11672	9046	37244	255
<b>2020</b>	22764	19666	17427	59857	265
<b>Total</b>	64223	51753	40355	156331	

Source: Own elaboration based on BDC

Regarding the dataset considered, CEIBAL provided a list of attributes from which a subset of variables included in the analysis model was selected. The metadata provided by CEIBAL consisted of records for 23 usage attributes and 8 grouping variables.

The first stage of the empirical work focused on analyzing logins to PAM through a descriptive and exploratory approach to the data. This analysis involved identifying measures of central tendency and measures of dispersion, as well as summarizing the variables related to access, coverage, and intensive usage of the platform. Subsequently, indicators of usage and creation of visual representations were generated to gain further insights into access statistics. Finally, hypothesis testing strategies were employed to determine the degree of association between PAM access and social factors.

In the second stage of the empirical work, the focus shifted to examining the student-platform interaction by combining a descriptive approach with a subsequent explanatory analysis through pertinent hypothesis testing based on variable measurement levels. The analysis of the results relied on the use of specific software for large data volumes (SPSS

Statistics V22, XLSTAT and Weka) and on design and geographical distribution applications, such as Maps in Seconds, to visualize variables based on the nineteen regions that constitute the territorial divisions of Uruguay.

### **Ethical Considerations and Data Analysis Limitations**

The research is framed in the ethical principles of confidentiality, anonymization and protection of the privacy of the people and institutions participating in the study. The datasets used for the analysis were prepared by CEIBAL's Data Processing Unit in accordance with the organizational data privacy policy.

All data used in this research were previously anonymized in the identification fields of students and schools. The datasets do not include any personal information, nor information about the student's performance when performing exercises on the platform. A confidentiality and information processing agreement was signed by the researchers responsible for the study.

The data presented in this article refer to an empirical correlational and census study. The findings should be interpreted within the framework of the limitations of the approach and the type of data collected, mainly those referring to the absence of records per student on school performance to analyze the impact on learning. Likewise, it would be relevant to contrast the results with studies supported by mixed methodologies, in order to advance in the knowledge of the effective use of technologies and platforms from a qualitative perspective.

### **Results**

For the analysis of the Database, three indicators were created: coverage rate (CR), activation rate (AR) and intensive usage rate (IUR) of the PAM platform, based on user records (students who had logged in for at least one day during the academic year and

engaged in some activity on the platform), active users (students who logged in to the platform for a minimum of ten days throughout the school year) and enrolment.

The coverage rate is an indicator that calculates the ratio between the number of users and student enrolment, and it is expressed as a percentage.

Similarly, for the purpose of this study, the activation rate was defined as the ratio between the number of active users and the total number of users, and the intensive usage rate as the proportion between the number of active users and the enrolment, both indicators are expressed as a percentage.

**Are there differences in terms of coverage, activation, and intensive usage of PAM based on the grade levels that students were enrolled in during the previous years and during the COVID-19 pandemic?**

One of the questions addressed in this study was whether there were differences in the coverage, activation and intensive usage of PAM based on the grade levels that students attended in the years prior to and during the COVID-19 pandemic.

Among the main findings of the study, it is worth noting that coverage rates decreased as students progressed through the grade levels, a trend observed both before and during the COVID-19 pandemic. On the other hand, a higher increase is observed in the upper-grade levels when comparing coverage rates between 2019 (pre-pandemic year) and 2020 (the onset of the pandemic in Uruguay) for each grade level of lower secondary education. During this period, the coverage rate doubled in ninth grade, increased by approximately 67% in eighth grade, and had the smallest increase in seven grade (42.5%). Furthermore, when considering all students in lower secondary education (total number of students in 7th 8th and 9th grade) it can be seen that the coverage rate doubled in the period from 2017 to 2020, as shown in Table 2.

**Table 2**

Year	Grade	Enrolment	Single Users	Active Users	Coverage	Activation	Intensive Usage
2017	1	42297	12365	6353	29	51	15
2017	2	39817	8597	3253	22	38	8
2017	3	40978	6300	2167	15	34	5
2017	Total	123092	27262	11773	22	43	10
2018	1	40504	11467	5574	28	49	14
2018	2	39667	10642	4370	27	41	11
2018	3	43155	6729	2186	16	32	5
2018	Total	123326	28838	12130	23	42	10
2019	1	38915	15732	8315	40	53	21
2019	2	37379	11056	4245	30	38	11
2019	3	42098	8488	2771	20	33	7
2019	Total	118392	35276	15331	30	43	13
2020	1	37502	21277	10603	57	50	28
2020	2	36324	18063	7361	50	41	20
2020	3	38942	15771	4546	40	29	12
2020	Total	112678	55111	22510	49	41	20

Source: Own elaboration based on BDC

The activation rate exhibits a similar trend to the coverage rate, showing a decrease when each level is compared within the same year. However, when referring to the activation rate of all students in Lower Secondary Education in the period 2017-2020, it remained practically constant at around 42% with a one percentage point fluctuation.

Likewise, when examining the intensive usage rates of all students, it is observed that there was a 30% increase over a three-year period in the pre-pandemic period from 2017 to 2019. However, in 2020, there was a significant increase of 54% driven by the impact of the COVID-19 pandemic.

**Are there statistically significant differences in the use of PAM based on gender, institution size, region, year, and grade level completed by the students?**

In addition to the descriptive approach, it was intended to study whether there are significant differences in the average number of: days of access to the PAM platform, activities and series completed, and stars obtained by the students according to socio-

demographic factors such as gender, region of the educational center attended by the student, grade level and size of the educational institution.

After confirming the normal distribution of the variables using the Kolmogorov-Smirnov test, the student's t-test was employed for the gender and region variables and the ANOVA test for the grade level and school size variables, to evaluate whether the differences in means between the observed groups occurred by chance or not.

Table 3 shows the significant values (bilateral significance) of the parametric coefficient used in each case. The procedure used for the analysis relates each of the four socio-demographic factors under consideration (independent variables) to the four dependent variables included in the model.

**Table 3**

*Analysis of Observed Differences in Usage According to the Hypothesis Testing of Associated Factors*

	Gender		Region		Grade Level			Size of the Institution			
	F	M	Mon.	Int.	7 <sup>th</sup>	8 <sup>th</sup>	9 <sup>th</sup>	S	M	L	
Days of logins	6.02	5.63 *	5.35	5.95 *	6.79	5.22	4.97	**	6.73	6.01	4.36 **
Completed activities	178.84	185.51 *	139.33	194.41 *	235.00	160.00	116.00	**	349.60	182.31	116.33 **
Completed series	17.50	20.24 *	11.62	21.23 *	23.19	17.99	12.55	**	62.21	15.11	9.70 **
Stars	4.54	4.90 *	2.14	5.58 *	6.93	3.54	2.54	**	14.27	2.90	1.92 **

(\*) Student's t-statistic is analyzed - Significance level adopted  $p < 0.05$  significant at 95%

(\*\*) The One-Way ANOVA statistic is analyzed for categorical variables with three levels-Significance level adopted  $p < 0.05$  significant at 95%

Source: Own elaboration

Using the statistical testing, it was possible to identify that gender had a favorable impact on the number of days of login, being female students the ones who logged in to the platform the most. The gender-related significant differences placed the mean ratings of female students above those of male students regarding login days (Female  $x=6.02$ ,  $p=.00$  and Male  $x=5.63$ ,  $p=.00$ ). Similarly, statistically significant differences were found regarding the variables of completed activities, completed series and stars, with averages



in favour of male students. This leads to the conclusion that male students have a more assertive interaction and utilization of the resources provided by the platform.

In relation to the parametric tests involving the region variable, significant differences in favour of the interior of the country were observed. There, students exhibited higher logins rates than those from Montevideo (Interior  $x=5.95$ ,  $p=.00$ , Montevideo  $x=5.35$ ,  $p=.00$ ). Subsequent sections of this article will explore this variable in more detail by exploring the differences among the various departments across the country.

Moreover, the significance test conducted made it possible to identify that the school grade level has a positive influence on the number of login days, with seventh graders having the highest average number of logins. The results indicate that seventh-grade students accessed PAM more frequently than the rest of the students in the other grades (7th grade  $x=6.79$ ,  $p=.00$ , 8th grade  $x=5.22$ ,  $p=.00$  y 9th grade  $x=4.92$ ,  $p=.00$ ).

On the other hand, statistically significant differences were found regarding the variables “completed activities,” “completed series” and “stars.” Specifically, seventh-grade students outperform their counterparts in 8th and 9th grade and the most significant difference was observed in the number of stars achieved by students in this grade level. Their average ( $x=6.93$ ) was nearly twice the number earned by eighth-grade students ( $x=3.54$ ) and almost three times the average of ninth-grade students ( $x=2.54$ ).

Additionally, Table 4 presents the statistical testing values for the educational institution size variable and allows us to affirm that there are significant differences favoring smaller centers in relation to the four variables that were proposed for the analysis. In small schools, the use of technologies was more frequent than in large-scale schools (small  $x=6.73$ , medium  $x=6.01$  and large  $x=4.36$ ). This means that the reward system based on gamification (Stars), which aims to enhance student motivation and foster the desire for

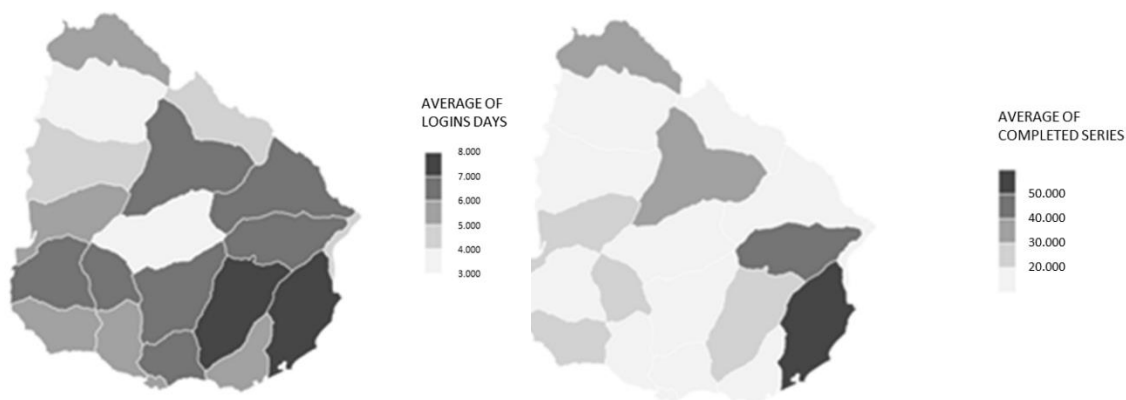
self-improvement, shows a significantly higher average in small schools compared to medium and large schools.

The study on the variations in access based on the country's regions, reveals that the departments located in the northwest of Uruguay exhibited the highest average number of platform login days. In the eastern region, Rocha and Lavalleja had an average of almost 8 login days, while in the western region, Cerro Largo and Treinta y Tres the average number was 7 login days. The national average was close to 6 days.

Likewise, those regions in which students interact with the platform the most were also characterised. Substantial variations were observed between the national average, nineteen completed series, and the averages of the departments with the highest completion averages, such as Rocha (74 series) and Treinta y Tres (47 series). Durazno, on the other hand, is the department with the lowest average value, with only 6 series completed. These findings are effectively visualized through the heatmaps depicted in Figure 1.

**Figure 1**

*Georeferenced Heatmap with Login Days and Completed Series*

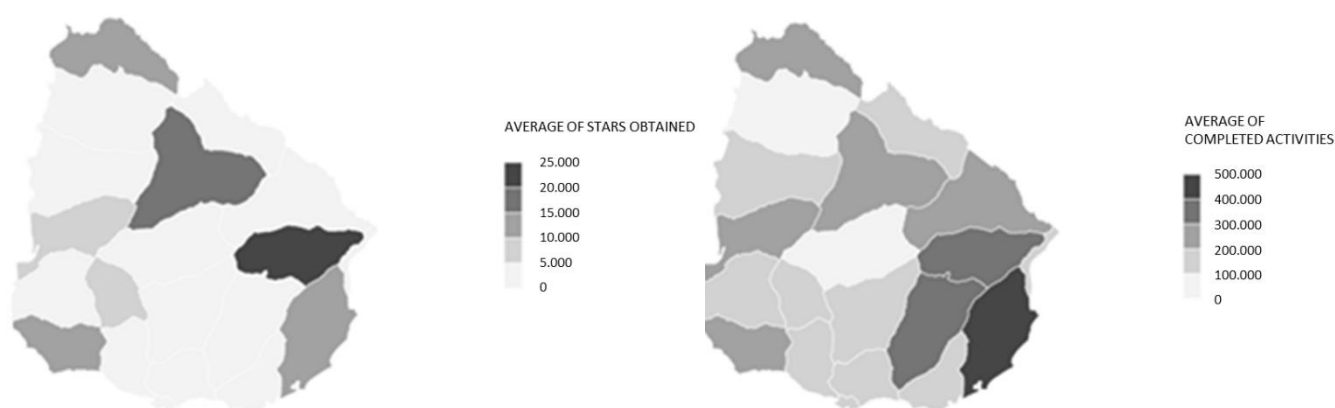


Source: Own elaboration

The variations in PAM's reward system show favorable outcomes for Tacuarembó and Treinta y Tres, with average values of approximately 24 and 19 stars, respectively. These values greatly surpass the national average, which is almost 5 stars. Conversely, Durazno, with an average of one star, is the department where the lowest average number of rewards provided by the platform is found. The heatmaps presented in Figure 2 provide a visual representation of these findings.

**Figure 2**

*Georeferenced Heatmaps of Completed Activities and Stars*



Source: Own elaboration

The departments situated in the eastern region of the country exhibit the highest average values in terms of both student interactions with the platform and the number of stars earned.

The statistical analysis and subsequent hypothesis testing regarding the average number of completed series, which serves as an indicator of the student interaction with PAM, revealed that male students exhibited a higher engagement than female students in this variable ( $p < 0.001$ ) (Male  $x = 20.24$  and Female  $x = 17.58$ ). Additionally, the remaining causal variables considered account for the variations in this proxy measure of platform effectiveness. Indeed, the evidence shows that students from the interior of the country

completed more PAM series than those from Montevideo, ( $p=0.00$ ) (Interior  $x=21.23$  and Montevideo  $x=11.62$ ), as well as students enrolled in seventh grade when compared to higher grade levels ( $p=0.00$ ) (7th grade  $x=23.19$ , 8th grade  $x=17.99$  and 9th grade  $x=12.54$ ). Furthermore, small-scale centers exhibited significantly better outcomes compared to the other centers analyzed ( $p=0.00$ ) (small  $x=62.21$ , medium  $x=15.11$  and large  $x=9.70$ ).

In line with the previous analyses, a recurrent pattern of behavior emerges when looking at the average number of activities completed by students on the platform. In this regard, there are significant differences in terms of gender, with male students having completed more activities than female students ( $p=0.00$ ) (Male  $x=185.51$  and Female  $x=174.84$ ). The region also plays a favorable role, as evidenced by a higher frequency of completed activities observed in the country's interior ( $p<0.001$ ) ( $x=194.41$ ) compared to Montevideo ( $x=139.33$ ). Confirming the results observed in the other interaction variables, seventh-grade students ( $p<0.001$ ) (7th grade:  $x=235$ , 8th grade:  $x=160$ , and 9th grade:  $x=116$ ) and students from small-scale educational institutions (small:  $x=349.50$ , medium:  $x=182$ , and large:  $x=116.33$ ) exhibited a significantly higher frequency of platform usage.

The use of stars by teachers is a strong indicator of how the reward system envisaged by PAM provides information about the level of student interaction with technology. Once again, the findings indicate that male students outperformed female students in terms of earning stars ( $p<0.001$ ) (Male:  $x=4.90$  and Female:  $x=4.54$ ) and that students from the interior of the country, seventh-grade students and those attending small-scale schools exhibited a significantly higher level of interaction: ( $p<0.001$ ) (Interior:  $x=5.58$ , Montevideo:  $x=2.14$ ), ( $p<0.001$ ) (7th grade:  $x=6.93$ , 8th grade:  $x=3.54$ , and 9th grade:  $x=2.54$ ), ( $p<0.001$ ) (Small:  $x=14.27$ , Medium:  $x=2.90$ , and Large:  $x=1.92$ ).

## **Discussion**

The results obtained from the exploratory study of the variables of access and interaction of students with the Bettermarks platform in the country, spanning both pre-pandemic and pandemic years in Uruguay, have enhanced our understanding and enabled us to address the specific objectives that guided our research.

Firstly, concerning the access to the platform variables, we found evidence indicating an increase in the number of days students accessed PAM in the year 2020 when compared to the three years preceding the pandemic. This finding aligns with the findings of national studies (Administración Nacional de Educación Pública [ANEP], 2021; INEE, 2022) that collected data on access to other educational platforms such as CREA (a general platform that provides resources in a virtual classroom format for all teachers, regardless of the content), which witnessed an increase in student access during the year 2020 by up to five times. Additionally, these findings validate the results of international studies that highlight the impact of utilizing platforms for teaching mathematics during COVID-19 quarantine and lockdown periods across the region and Europe (Spitzer & Musslick, 2021).

The analysis of big data and the subsequent knowledge discovery derived from the usage patterns recorded in the databases provided by CEIBAL enabled the confirmation of a slight increase in the intensive usage of PAM during the specified period of time, but with a low overall coverage percentage. This finding aligns with the conclusions drawn from a recently published study carried out by CEIBAL and UNICEF (2023), which, by the year 2022, found a low frequency of PAM usage, with a mean value between one and two days per student per year. Similarly, the intensity of usage of this platform was very low. Moreover, the results also revealed the existence of high heterogeneity in the access to PAM, as well as the incidence of the social factors considered. It was found that the frequency of single students' access to PAM was higher in 2020 than in previous years,

and higher in seventh grade than in the rest of the grade levels. Additionally, on average, female students accessed PAM more frequently than male students and students from the interior of Uruguay have higher access rates compared to those living in Montevideo. A greater level of access is observed in the northwest region of Uruguay, where the highest averages of platform login days are seen. The departments of Rocha and Lavalleja have an average of close to 8 login days, followed by Cerro Largo and Treinta y Tres in the western region, with an average of 7 login days. The national average is approximately 6 days.

The significant heterogeneity in students' behavior regarding access to PAM supports the conclusions of previous studies conducted in the country. These studies have indicated the existence of usage disparities based on gender (ANEP, 2021; INEE, 2022) as well as the incidence of structural factors such as the geographical location from where students connect, this being a specific finding for which no precedents in our country or the region have been found.

Secondly, concerning students' behaviours based on the interaction with PAM variables that were incorporated into the analysis models, the findings reveal a positive association with respect to the region (the interior of the country has a higher usage profile than the capital, Montevideo), grade level (twelve-year-old students enrolled in the seventh grade of compulsory lower secondary education make more intensive use of all the interaction variables), and school size (institutions with fewer than 400 students have learners with a greater likelihood of utilizing the platform).

An important discovery in this study pertains to the confirmation that gender plays a significant role in the utilization of the platform, with male students consistently exhibiting higher usage than female students across all three interaction examined variables (activities, series, and stars). These findings contradict previous research conducted in

Uruguay, which found no significant differences based on gender in the impact of PAM usage on mathematics learning in primary education (Perera & Aboal, 2019), as well as international reports (Spitzer & Musslick, 2021).

In summary, among the main findings of this study, it is worth highlighting the identification of independent effects regarding the gaps in access, interaction, and use of technology in the mathematics classroom based on the variables of usage context that were considered.

The heterogeneous usage patterns observed in the Bettermarks platform (PAM in Uruguay) are most likely the result of significant disparities in access to digital resources. Despite the country's significant progress in bridging this gap, according to INEEd (2022), 30% of students still do not have access to digital educational resources. Additional explanatory factors not considered in this study should also be examined, such as how schools and teachers use digital educational technologies and platforms (Hinostroza, 2017).

In light of the results, at least three challenges are evident for achieving greater effectiveness in teaching and learning mathematics. Firstly, it is necessary to ensure universal, consistent, and equitable access to the Internet inside and outside the school settings (Elena-Bucea et al., 2021; INEEd, 2022). Secondly, it is important to understand to what extent teachers make effective use of usage reports and access analytics provided by digital platforms to tailor their teaching strategies, for which it would be necessary to promote new studies using a qualitative approach.

Lastly, a pending challenge would be to ensure that education systems promote institutional strategies and educational policies addressing the digital inequalities in access to knowledge. While these inequalities existed prior to the pandemic (Dewan et al., 2010), they have intensified since then, and have widened the usage gaps between

connected, partially connected, and disconnected students regarding the utilization of the potentials of the Internet, digital resources and learning platforms in times of COVID-19 confinement periods (Rivas, 2021).

## **Conclusions**

The utilization of digital platforms in mathematics education holds immense potential for fostering inclusivity and enhancing learning. In Uruguay, notable progress has been made in educational policies aimed at providing universal access to digital educational resources. A relevant case is the incorporation of the Bettermarks platform for mathematics teaching, primarily used in lower secondary education.

In Uruguay, CEIBAL has an open data policy that enables an analysis of the influence of several factors on the utilization of the digital platform available to the Uruguayan education system. This study analyzed a substantial dataset encompassing the main actions performed by students on the platform between 2017 and 2020. Over the course of the study period, there was a progressive rise in both access to the Bettermarks platform and the activities carried out by students.

This study tested multiple hypotheses to explain the heterogeneities in student access and interaction patterns. Significant statistical differences were identified in terms of coverage and activities performed by students based on factors such as year, gender, region, grade, and school size. Concerning gender, female students had higher access coverage, while male students exhibited more intensive interaction. Moreover, utilizing georeferenced data, higher usage rates were observed in the interior of the country compared to the capital city, Montevideo.

The conducted analysis provided insights into the changes in platform usage during the peak of the COVID-19 pandemic. In terms of absolute coverage, it was higher during



2020; however, when comparing the relative activity rate between years, no significant differences were found.

The findings demonstrate the long-term impact of a public policy aimed at achieving universal access to digital educational resources. Nonetheless, the challenge still remains to go beyond basic measurements of access and coverage and explore, in greater detail, how students and teachers effectively use these platforms.

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**Authorship contribution:**

**Eduardo Rodríguez Zidán:** Concepción y diseño, Recopilación de datos, Análisis e interpretación de datos, Metodología, Redacción del artículo.

**Gustavo Bentancor Biagas:** Recopilación de datos, Análisis e interpretación de datos, Metodología, Redacción del artículo

**Martin Solari:** Recopilación de datos, Análisis e interpretación de datos, Metodología, Redacción del artículo.

**Declaration of no conflict of interest:**

The authors declare no conflict of interest.

**Source of funding:**

Fondo Sectorial de Educación, Fundación CEIBAL y Agencia Nacional de Investigación e Innovación (ANII) – Uruguay (FSED\_2\_2020\_1\_163598)

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