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Task design to support preservice teacher development of statistical graphic critical thinking skills

José Carlos Casas-Rosal[1] | **Carmen León-Mantero**[1] | **David Gutiérrez-Rubio**[1] | **Orlando Arencibia**[2]

[1]Facultad de Ciencias de la Educación y Psicología, Universidad de Córdoba, Córdoba, Spain

[2]Ekonomická Fakulta VŠB-TU Ostrava, Ostrava, Czech Republic

Correspondence
Carmen León-Mantero, Facultad de Ciencias de la Educación y Psicología, Universidad de Córdoba, Córdoba, Spain.
Email: cmleon@uco.es

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Abstract

Critical thinking is a skill that people must develop to navigate skillfully the information they receive through media channels. The cultivation of this skill must begin in the early stages of education and continue uninterrupted through the completion of academic training. For this reason, the search for tools to promote critical thinking in the classroom is crucial. To address this situation, it is essential that the initial training of educators provides them with valuable resources, offering them a tool for supporting critical thinking in their own future classrooms. This paper presents an activity to cultivate statistical graphic critical thinking (SGCT task) of preservice teachers, offering them a tool for their future teaching role. This approach is implemented dynamically, incorporating real-world information and simulating individuals' everyday situations. The proposal, implemented with a cohort of 60 preservice teachers, has proven beneficial in improving the critical thinking skills of participating preservice teachers.

KEYWORDS

critical thinking, graphical information, preservice teacher, teaching statistics

1 | INTRODUCTION

In today's society, the media are fully integrated into all facets of people's lives, regardless of their age or socioeconomic characteristics. The information disseminated through these media channels is broad and immediate. While this context offers many opportunities, there are also inherent threats, such as fake news or misinformation. The latter can be defined as information containing falsehoods disseminated in a news format, often motivated by political agendas.[5]

Citizens must understand, evaluate, and analyze messages accurately to combat this information effectively. In other words, consumers need to engage in critical thinking. One of the prominent authors in developing the concept of "critical thinking" is Robert Ennis, who defined it as rational and reflective thinking, consisting of cognitive and attitudinal aspects, intending to decide what to do or believe.[7] Metacognitive skills must be added to these dimensions to complete this definition, according to Kuhn and Weinstock.[12] Unlike cognitive and attitudinal aspects, metacognition is a second-order skill that involves knowing one's knowledge and that of others. Therefore, critical thinking is second-order thinking since it requires thinking about one's thinking, not just thinking. In a more specific sense, Piette defines critical

thinking as the process through which skills related to clarifying information, forming judgments about the reliability of information, and evaluating information to conclude are acquired.[14]

Therefore, developing critical thinking allows citizens to effectively confront information that introduces bias intending to influence opinions in a particular way. However, various studies evaluating an individual's degree of critical thinking have yielded unsatisfactory results[3, 15] including personal perceptions (poor self-perception of critical thinking ability), poor metacognitive skills, and a fixed mental focus.[13] Other studies suggest how it can be developed.[9, 11]

Furthermore, when people are faced with information from a specific field, such as statistics, its interpretation requires additional skills, which may increase the difficulty of critical thinking. An important aspect is that statistical information is persistent in different media.[6] More specifically, the most frequent information is the statistical graphic, which is supposed to facilitate nonexperts' understanding of the message. However, some studies show that many people have significant difficulties reading and interpreting statistical graphs correctly, even at the most basic level.[10]

Statistics is taught in primary, secondary, and even many university studies. In recent decades, statistical educators have begun appreciating and recognizing the limitations of procedurally unrealistic approaches. It observes a shift from traditional, procedure-focused teaching methods to approaches prioritizing conceptual understanding and real-world application.[13] The inseparability of context, inherent to this discipline, must serve as a starting point for improving its teaching.

Moreover, although numerous pedagogical proposals address critical thinking about media information at the secondary level,[9, 16] as well as in higher education,[2] the results in terms of the development of students' critical thinking are systematically unsatisfactory. Therefore, there is an urgent need to implement proposals in the classroom that more effectively promote the development of critical thinking and simultaneously promote teacher training.[17] For the reasons mentioned above, this need becomes even more evident when the information is statistical-graphic.

This work proposes a classroom task to develop the statistical graphic critical thinking (SGCT) of primary preservice teachers, which is essential to fostering future generations' critical thinking. Consequently, this study seeks to develop a task in the grade of primary education classroom that allows for the cultivation of statistical critical thinking among preservice teachers and motivates them to implement similar tasks or adaptations with their future primary children with similar objectives.

2 | FROM MISTAKES TO PURPOSE

This proposal has been designed for third-year preservice teachers in the primary education grade at the University of Córdoba in Spain. Its main objective is to develop SGCT by confronting preservice teachers with graphical statistical information collected from different media. This information often contains essential errors hidden behind a specific intention, disguised under the appearance of rigor provided by statistical data.

The task was designed to develop the SGCT in elementary school preservice teachers by training them to transform the statistical information they received into knowledge and to acquire skills that would allow them to make value judgments about incorrect information. It allowed them to reduce their credulity in the face of this type of information. In their future teaching roles, they will need to develop critical thinking skills in their children, which would be difficult if they lacked these skills themselves.

The SGCT task was conceived as a competence-based teaching-learning process in which preservice teachers are the protagonists. The activity was designed to challenge the preservice teachers and to promote solutions through collaborative work and independent research. It also aimed to make the preservice teachers reflect on the importance of developing and promoting this skill in their future primary children.

It was conducted in three small groups of 20 preservice teachers to facilitate the successful completion of the different dynamics of the activity, and its approximate duration was 120 min. In the following sections, the SGCT task is developed in detail.

Time and language played a central role in the SGCT task, as the time to analyze the graphic information, sometimes in languages other than the native language, was limited. The goal was to simulate the everyday environment where information is consumed quickly and sometimes in languages other than one's own. For this reason, graphs have been provided in English, German, Czech, and Norwegian.

All of these graphs are real because some media previously published them. On the other hand, although the information given in the statistical graph was not suitable for primary school children due to its difficulty, the skills needed to identify errors would be suitable for children from this stage on. The preservice teachers will develop their future teaching work in this stage.

2.1 | Statistical graphic critical thinking task: Introduction

Initially, an online search was carried out for graphic information from various media outlets worldwide that contained errors, in many cases, with a clear intention to hide reality or transmit information different from that offered by the data. It is noteworthy that an essential part of the motivations was political. The search for graphs was a tedious process because, although there are numerous examples of erroneous graphs on the Internet, the criteria for inclusion were that the errors they contained were identifiable from knowledge of the basic guidelines for graph representation, that there were examples in which the information was insufficient and that the source from which these graphs came could be verified. In summary.

Finally, 30 graphs were selected from different media, such as paper or digital newspapers, newscasts, or even posts on X (Twitter) from political leaders. These were analyzed in detail by the university lecturer, who finally identified 17 types of errors in the way of representing information. Some errors were found in graphs on a specific basis, and others were generally present errors, such as lack of rigor in the representation. For example, error two could occur when representing data from a qualitative variable using histograms or when constructing pie charts when the sum of the percentages of the different categories does not necessarily have to be 100. These can be consulted in Table 1. The selected graphs were printed in color in A3 format, identified with numbers, laminated, and Velcro strips were glued on the back to adhere them to flannel boards (60 x 90 cm).

Description cards were made with each error identified with numbers. Each group was given 17 error cards of one color, and each group was identified by the color of the cards they were given. They were asked to spread the cards on the table and reread them carefully to ensure they understood them correctly. In this way, class groups were identified by the color of the error tokens. These tokens were cut and laminated, and Velcro strips were attached to the back, later used to attach to the flannel board. For each session, the teachers selected 10 of the 30 graphs based on the aspects they wanted to highlight, such as the reason for the manipulation, the type of error found, or the level of difficulty observed.

The five flannel boards were prepared by dividing their surface into five regions, as shown in the example in Figure 1. In the two upper regions, the teacher glued two of the chosen graphs, separated by a vertical line, and glued them with Velcro. The flannel board's bottom left and right regions were reserved for the preservice teachers to place the error tokens from the top two graphs. The bottom center region, below the separation line, was reserved for the preservice teachers to paste errors that they considered common to the two graphs, if any.

The response template was created for each of the five flannel boards that the preservice teachers subsequently analyzed. Figure 2 shows this template has a format similar to a flannel board. The information collected is the numerical identifier of the two graphs analyzed, the numerical identifier of the errors found in each graph, and the intention of the informant with the manipulation of the graph, if any. It should be noted that in this case, the errors common to the two graphs must be written repeatedly below each graph.

Finally, the university lecturer created five walls in the PADLET application, which were later used to evaluate and discuss the errors present in the graphs of each flannel board and the intention of the manipulation.

TABLE 1 Types of errors found in the provided graphs, along with their numerical identification.

ID	Error	ID	Error
1	Insufficient information to interpret the graph correctly	10	Incomparable values
2	Incorrect selection of the graph	11	Uses images in a biased manner
3	Lack of proportionality between different categories	12	Uses colors in a biased manner
4	The sum of the percentages is not 100%	13	Uses multiple scales in a biased manner
5	Missing information on the axis corresponding to frequencies	14	Introduces accessory elements that try to influence perception
6	Does not start counting frequencies or percentages from 0	15	Different thickness of bars
7	Categories are not correctly positioned on the x-axis	16	Inadequate size of pictograms
8	Confusing graph	17	Not a rigorous graph
9	Incorrect selection of colors		

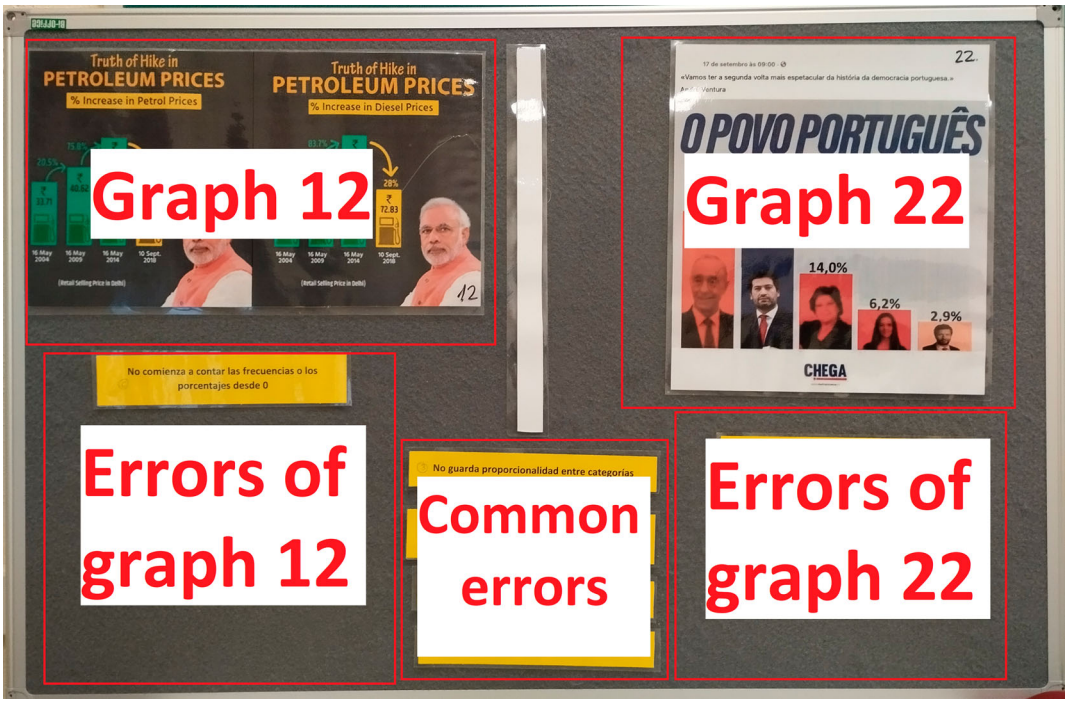

FIGURE 1 Completed flannel board example. [Colour figure can be viewed at wileyonlinelibrary.com]

Round 1. (10 min.)

ID Graph:				ID Graph:			
ID errors:				ID errors:			
Objective of manipulation:				Objective of manipulation:			

FIGURE 2 Response template.

2.2 | SGCT task: Identifying the problem

At the beginning of the session, the university lecturer raised the problem that people often receive graphic information that contains errors, which in some cases are deliberate and aimed at leading to opinions different from those supported by the data.

Then, the university lecturer explained in detail and with examples each of the 17 errors to be worked on, which are listed in Table 1. They were also shown three erroneous graphs, different from the ones they would later work on, for which the errors were identified, and the existence or not of an objective to manipulate the graphs was discussed.

Following the university lecturer's explanation, the tutor facilitated the exploration of the three graphs, guiding the discussion so that the preservice teachers could identify the different errors present in the graphs and draw their conclusions about the intentionality of the manipulation. Preservice teachers raised various questions about the conceptualization of some of the errors in the list, how these can be identified in statistical graphs,

FIGURE 3 Example of a flannel board delivered to preservice teachers. [Colour figure can be viewed at wileyonlinelibrary.com]

and the possible changes in perception that these errors can cause (for example, by not starting the frequency scale from 0 in a bar chart). After some time in which these doubts raised by the preservice teachers were resolved, the university lecturer divided the class into five groups of four, with random grouping.

They were then told that they might need a cell phone with an application (e.g., Google Translator) that would allow them to translate text into other languages (English, French, Portuguese, German, or Norwegian) based on the capture of an image since a large portion of the graphs to be analyzed would be in languages other than their native language. It allowed those who did not know it to become familiar with a valuable tool in today's globalized society. They were informed that there would be five rounds with decreasing availability of analysis time. Specifically, they would have 10, 9, 8, 7, and 6 min, respectively. As mentioned earlier, reducing the time in each round simulated a real-world context with limited time to evaluate the graphic information.

Each group was given a flannel board with two graphs attached to it with Velcro and a vertical dividing line between them, as shown in Figure 3. They were told that in the time available, they had to stick the error tokens under the graphs as indicated in the previous section, photograph the resulting configuration of the flannel board, and fill out the response template indicating the goal that the creator of the graphic might have had in manipulating it, if any. They were initially asked to analyze the graphs, identify the errors present, and then choose those that matched their assessment from the cards provided.

Approximately 30 s before the end of each round, they were told to remove the errors from the flannel board, thus preparing it to be given to the next group. Figure 4 shows the photo taken by one of the groups of one of the flannel boards.

Each group had analyzed the 10 graphics provided by the end of the five rounds. After discussion among group members, one graph (from the 10 graphs displayed) was selected for the group to try to draw correctly.

Meanwhile, the university lecturer asked the preservice teachers to upload the five photos they had taken onto the five walls he had previously created in the PADLET application. Each of these walls should contain a photo of the same flannel board of the five groups. To do it, the QR codes were projected on the board together with the numerical identification of the panel board. This allowed the university lecturer to prepare the second part of the SGCT task.

2.3 | SGCT task: Second part

Once the first part of the activity was completed, in which the different groups of preservice teachers had filled in the flannel boards with the error cards, photographed the results, uploaded them to the PADLET walls, and filled in the response templates identifying the possible goals of the manipulation and tried to correctly

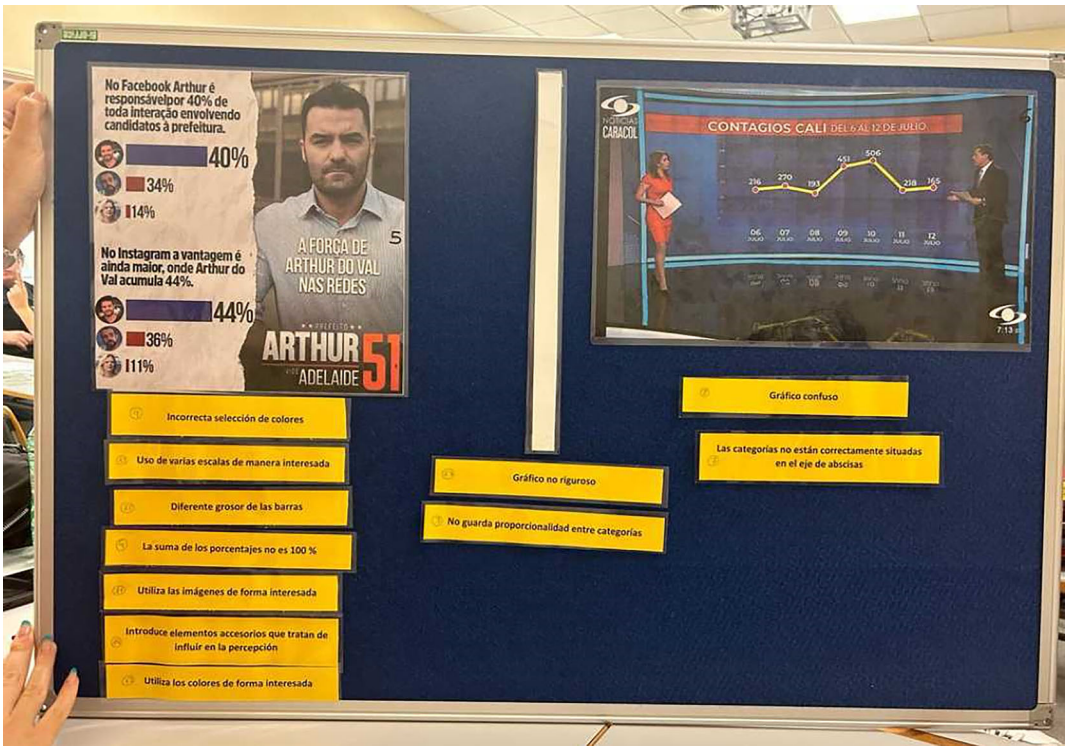

FIGURE 4 Example of a flannel board completed by preservice teachers. [Colour figure can be viewed at wileyonlinelibrary.com]

FIGURE 5 Example of a PADLET wall. [Colour figure can be viewed at wileyonlinelibrary.com]

represent the chosen graph, the second part of the SGCT task, in which the answers given were analyzed began. A debate was held about the errors in the different graphs and the possible existence of an intention to manipulate each.

For this purpose, the PADLET walls were used with the photographs sent by each group for the subsequent debate and discussion. These showed the error tokens chosen by each group for the two graphs presented, and the color of the tokens identified the group that had given each answer. In this way, all groups could consult the answers given by the others and their similarities and differences with their answers. An example of a PADLET wall is shown in Figure 5. Although the size of the images makes it impossible for the reader to identify the error tokens

chosen by the groups, they are specified for analysis in the following section.

First, the sheets with the errors most frequently considered by the different groups were analyzed, and their appropriateness was examined and discussed. Then, the less common errors were analyzed, always trying to investigate the reasons for their consideration. Finally, errors that had not been considered by any groups but were present in the diagram were analyzed, if any. Time was left for reflection and discussion; later, the university lecturer gave the appropriate justification.

Also, on each PADLET wall, one group was asked to explain the possible motivations that could have led to the errors identified if they were considered intentional. After the presentation, a debate with the other groups was encouraged.

It is important to note, which was done during the session, that the time available to complete the flannel board differed for each group on the same PADLET wall. That is because the flannel boards were transferred to another group in each round, and the rounds had a decreasing time available.

At the end of the session, each group presented the graph they had selected and represented to the rest of the group, correcting the errors found in the original graph. They were asked to explain why they had chosen this graph and what elements they had corrected. Finally, the preservice teachers voluntarily and anonymously filled out a questionnaire to collect their opinions about the activity, the results of which will be briefly discussed in the following section.

3 | EVALUATION

In this section, the SGCT task will be evaluated through the responses to each of the tasks given to the preservice teachers and the questionnaire administered at the end of the session. Therefore, the results of identifying errors and the intentionality of manipulating the graph will be analyzed with general data and some examples. How the preservice teachers represented the previously selected graph will also be analyzed.

Figure 5 shows the flannel boards filled with the error sheets of the five groups from one of the three sessions. These groups were the Pink, Blue, White, Yellow, and Red teams. The answers given are illegible due to the size of the pictures but are shown in Table 2, along with a translation of the summary of the manipulation goals proposed by the five groups in graphs 12 and 22. These graphs are better seen in Figure 3.

Graph 12 shows the evolution of the price of gasoline and diesel in such a way that, at first glance, an apparent decrease in the price can be seen in the latest data, which is unrealistic since the data offered indicate that it went from 71.41 to 80.73 rupees per liter in the case of gasoline and from 56.71 to 72.83 rupees per liter in the case of diesel. In addition, the image of the Prime Minister of India, Narendra Modi, gives a greater sense of credibility. Therefore, the graphs do not maintain proportionality between categories; there is a lack of information on the frequency axis; they use colors in a biased way to highlight a specific moment; they introduce accessory elements such as arrows to try to influence perception and, therefore it is not rigorous (errors 3, 5, 12, 14, and 17).

On the other hand, graph 22 shows the voting intentions of five candidates in the first round of the presidential elections in Portugal, giving a disproportionate weight to one of the candidates, André Ventura. He receives only 9.4% of the voting intention, compared to 60.3% for the first candidate and 14% for the third. Therefore, the graph does not respect the proportionality between the categories; there is a lack of information on the frequency axis, and it uses images and colors in a biased way; therefore, the graph is not very rigorous (errors 3, 5, 11, 12, and 17).

TABLE 2 Preservice teacher responses to graphs 12 and 22.

Graph	Group	Errors	The objective is...
12	Pink	3, 5, 7, 8, 12, 17	That the actual increase in prices is not appreciated.
	Blue	3, 8, 9, 11, 14	To compare the rise of oil and diesel over the years.
	White	1, 2, 3, 12, 14	To make people think that gasoline and diesel prices have decreased.
	Yellow	2, 3, 4, 8, 13, 14, 17	To make people believe that gasoline and diesel prices have decreased.
	Red	8, 9, 12, 13	To influence by making it look like it went down when the price went up.
22	Pink	3, 4, 5, 11, 12, 14, 16, 17	To influence the perception of politicians.
	Blue	3, 4, 8, 9, 12, 14, 16	To see what percentage of the population votes for each party.
	White	1, 3, 4	To make people think a political party has more support than it does.
	Yellow	3, 4, 8, 11, 12, 17	To highlight a political figure who has not been voted for as much as others.
	Red	3, 4, 11, 14	To make people focus on the candidate on a purple background in the image.

As we can see, similar errors are made in both graphs because although graph 22 does not contain any accessory elements, graph 12 also uses the image of the Prime Minister in a biased way. The answers given by the five groups in one session are shown in Table 2.

For graph 12, four out of five groups noticed a lack of proportionality between the categories. Furthermore, the use of colors was biased, and three groups noticed the introduction of accessory elements and the use of colors in a biased way. Only two groups indicated that the graph was not rigorous, and one stated that the information on the frequency axis was missing. On the other hand, it is worth noting that four out of five groups indicated the graph was confusing. Four of the five groups identified the goal of the graph manipulation, and it is surprising that the blue team did not correctly identify the goal, even though it had identified the lack of proportionality between categories and the introduction of accessory elements in the graph.

Regarding graph 22, it should be noted that all the groups recognized the lack of proportionality; three of the five saw the use of images and colors in a biased way, only two groups stated that the graph was not rigorous, and only one team recognized the lack of information on the frequency axis. On the other hand, all the groups recognized error 4, that is, that the sum of the percentages does not equal 100. This error occurred in a generalized way, and we worked on it in the second part of the SGCT task, explaining to them which types of graphs this condition is necessary for correct representation. It also makes them aware of the possible existence of other candidates with low voting intentions. Furthermore, four groups identified the goal of the manipulation although one of the answers was somewhat confusing (pink); and one of them (blue) did so incorrectly since it indicated the objective of the information, not its manipulation.

The graphs created by the preservice teachers generally accomplished what was required: correcting the errors observed in the original graphs. The most common errors were representing pie charts without accurately calculating the angle of the circular region, representing bar charts with the bars together as a histogram, or replicating one of the undetected errors.

For all groups, the success rate in detecting the errors in the graph was 55%, with a standard deviation of 11.5%. However, the assignment of errors not present in the graphs was high, with a mean of 1.94 per graph and a standard deviation of 0.73. On the other hand, the success rate in identifying the manipulation target was 57.6%, with a high dispersion given by the standard deviation value of 26.9%.

Finally, the responses to the questionnaire administered at the end of the SGCT task are briefly reported. Participants were asked to rate their level of interest in three aspects of the SGCT task using a 5-point ordinal scale, with 1 representing no interest and 5 representing maximum interest. The minimum score given by the preservice teachers on this scale was 3. For the first item: Rate on a scale from 1 (not very interesting) to 5 (very interesting) the interest you think there is in addressing statistical graphical critical thinking in the subject, 38.1% of the respondents gave a score of 4, and 54.8% gave the maximum level of interest, 5. For the second aspect, which deals with interest in doing the task collaboratively, 26.2% gave a score of 4, and the remaining 73.8% gave the highest score. Finally, when asked about their interest in working on critical thinking through the analysis of manipulated graphs, almost four out of five respondents (78.6%) considered it most useful.

4 | CONCLUSIONS

Critical thinking about information presented in graphs in media is a contemporary need for people due to the continuous flow of information received through various media channels.[18] It must be cultivated from the earliest stages of learning, with primary education as the fulcrum.[1, 13] In this context, teachers play a transcendental role at this stage.

Numerous studies have highlighted the need to promote critical thinking, given its importance for human development. Learning this skill becomes even more challenging when the information to be critically analyzed is statistical, which requires additional cognitive skills.[4] Information providers exploit this challenge by presenting statistical graphs.[6] Although these graphs usually contain accurate data, their presentation introduces a bias to the recipient, usually with a clear objective. In this context, incorporating critical thinking skills into educational curricula is crucial. However, it is not always implemented effectively, which can lead to the acceptance of false information.[18]

This paper presents a crucial task that involves authentic manipulated graphs meticulously scrutinized to detect errors. It aims to equip future teachers with the ability to discern the intention behind such manipulations. The choice of graphs, previously published in media worldwide, and the gradual reduction of analysis time heighten the engagement and perceived value of this task for preservice teachers.

The activity focuses on some of the critical thinking skills defined by Ennis,[8] such as determining the credibility of a source, making value judgments when information is sufficient and abstaining when it is not, dealing appropriately with errors and deception, thinking about assumptions, having the ability to change positions with sufficient evidence, using existing knowledge, understanding and

using basic graphs, and considering the context in which information is placed. This work proposes an activity to provoke preservice teachers to think critically about information presented in graphs that is political, environmental, or related to economics and to support them in developing critical thinking skills they can use in their own classrooms with primary students.

Given the importance of media in today's society, there is a pressing need to enhance the SGCT of preservice teachers. The high number of errors present in the proposed graphics not detected by the preservice teachers and the low rate of correct answers regarding the manipulation objective, even when placed in the context of graphic manipulation, highlight the need for more rigorous training. After the activity, most preservice teachers expressed indignation at the lack of governmental regulations preventing this type of information from reaching the public without oversight, often through conventional media channels as well. The surprise and concern expressed by these future educators regarding media bias and the need for stricter regulations further underscore the significance of this research.

This proposal has the potential to be flexibly applied across various educational levels, including primary education. By selecting or creating manipulated graphs tailored to the specific level, this task can effectively enhance critical thinking skills and awareness of graphic manipulation.

Initiatives aimed at developing critical thinking contribute to making people less susceptible to deception through graphic manipulation, thus increasing their freedom in a globalized world where information plays a central role. Consequently, it facilitates the improvement of social justice.

ORCID

José Carlos Casas-Rosal https://orcid.org/0000-0002-6954-6517
Carmen León-Mantero https://orcid.org/0000-0002-2870-8807
David Gutiérrez-Rubio https://orcid.org/0000-0002-4461-2223

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