Electronic Spreadsheets: Inconsistencies, Errors and Discrepancies

Jonas de Medeiros
University of the Joinville Region (UNIVILLE)

Rafael Alberto Gonçalves
Regional University of Blumenau (FURB)

The authors, over more than 10 years dedicated to research and scientific production, which have been shared through books and scientific articles focused on information and communication technologies in relation to education and the contemporary context of technological dependence in which society is inserted today, demonstrate not only logical and conceptual weaknesses in the application of spreadsheets, but also discuss new perspectives on the use of complex systems that simulate intelligence. Thus, the present article is developed around the importance of effectively knowing the fundamental mathematical calculations, before indiscriminately accepting the mathematical projections presented by the main tools available in the market. Inconsistencies, weaknesses, and errors, both logical and mathematical in spreadsheets, will be presented, as well as their possible impacts on the market and society.

Keywords: spreadsheets, mathematical errors, logical inconsistencies

INTRODUCTION

Initially, it is worth noting that the study from which this chapter derives is a continuation of the authors' work throughout their respective teaching careers, in which they were able to observe, through pedagogical praxis, many errors and inconsistencies in relation to the mathematical logic embedded in electronic spreadsheets. These inconsistencies have been, for more than 10 years, published in scientific articles and books related to information and communication technologies, especially in the intimate relationship between education and technology in our current context of society, where human dependence on technology borders on the visceral. However, it is important to understand that:

> It is common for academics and even market practitioners to refer to systems as having intelligence, whether they are computerized (as is the case with some software) or not when it comes to information technology. This is a common mistake, since computer systems are based on logic, i.e., mathematical calculations that confer evidence based on probabilities that come from equations, algorithms and arithmetic expressions that, however complex they may seem, only simulate what is known as intelligence. (Medeiros e Gonçalves, 2018, page. 51)

It is in this context that Medeiros and Gonçalves (2018) discuss the non-critical use of complex systems that simulate what many confuse for intelligence, where this chapter is developed around the importance of reliable mathematical calculations and projections, because it is based on this confidence that its simplified daily application comes from, or even its application in large economic-financial markets or even in military and strategic applications for governments and security entities.

> These applications in different segments reinforce the need for reliability in the results, not only for reasons of planning or concept checking, but mainly because the consequences of an erroneous projection can have repercussions on the whole of modern society, which is highly dependent on technological resources. (Medeiros e Gonçalves, 2018, page. 52)

And it is in this context that the studies, projects, and publications of the authors of this chapter are developed, which present inconsistencies, shortcomings and other logical and mathematical errors in the spreadsheets and their possible impacts, both in the market and in society.

It should be noted that regarding the impacts of errors, inconsistencies and non-conformities that will be presented for this work, both for the operations involving potentiation, as well as for the conflicts of results between the different tools available in the market. For this purpose:

> Following the ethical parameters of an academic research and prior to the publication of this study's results, several attempts were made to notify the developers of the tested applications about inconsistencies, deficiencies, and non-conformities, but without success. (Medeiros e Gonçalves, 2018, page. 69)

Therefore, the brands or developers of the spreadsheets tested will not be exposed in this chapter, however, it should be noted that, for ethical reasons, all developers of the tools used in the study were duly notified regarding the errors identified, however, it has not yet been possible to notice any correction in their applications.

DISCREPANCIES AND ERRORS BETWEEN SPREADSHEETS

Over time, during the development of didactic content for classroom application in professional and technological courses (high school, undergraduate and graduate technical courses) in disciplines focused on strategic management, financial mathematics, statistics and management tools and strategies, it was possible to observe that, when applying simple calculations in electronic spreadsheets, sometimes logical errors appeared that, without a consistent training in classical mathematical principles, would go unnoticed. And it was through a multi, pluri, trans and interdisciplinary dialogue involving technical and management disciplines that the impacts and consequences of these errors began to be fostered by the authors to the point of motivating an ongoing project involved in the identification, labeling and disclosure of these inconsistencies, which at the strategic level can lead companies to worrying scenarios.

> A lot of calculations involving sets, expressions such as mode and modal, as well as in the translation of simple mathematical models into the expressions adopted in electronic spreadsheets, have been inconsistent, thus generating erroneous or, rather, false results compared to what was expected. These results may seem insignificant, or simple, but if they are observed on larger scales, such as the application of mathematical models of stock markets around the world, they could cause real economic collapses, condemning society to a colossal setback, such as the Great Depression of the 1920s in the United States of America, the real estate bubble of 2008 in Europe, events that still have their consequences experienced today in Brazil. (Medeiros e Gonçalves, 2018, page. 55)

For this specific study, the authors focus this section of their studies on mathematical operations involving powers, for this, initially it is necessary to remember that according to the resolution properties for compound equations, the adoption of parentheses as ordering elements of the priority sequence in the mathematical execution of any formula, or algorithms, regardless of whether or not these involve the properties of exponentiation will be given as a factor, or even as a rule to adopt for resolutions whose ordering may interfere with the result, ensuring a calculation not only correct, but also reliable with its logical properties.

> Parentheses are used in all mathematical areas, so learning how to use them correctly is essential for better calculations. When we make operations between numbers, the parentheses determine the order and priority of one over the other. (GCF Global, 2020, Web)

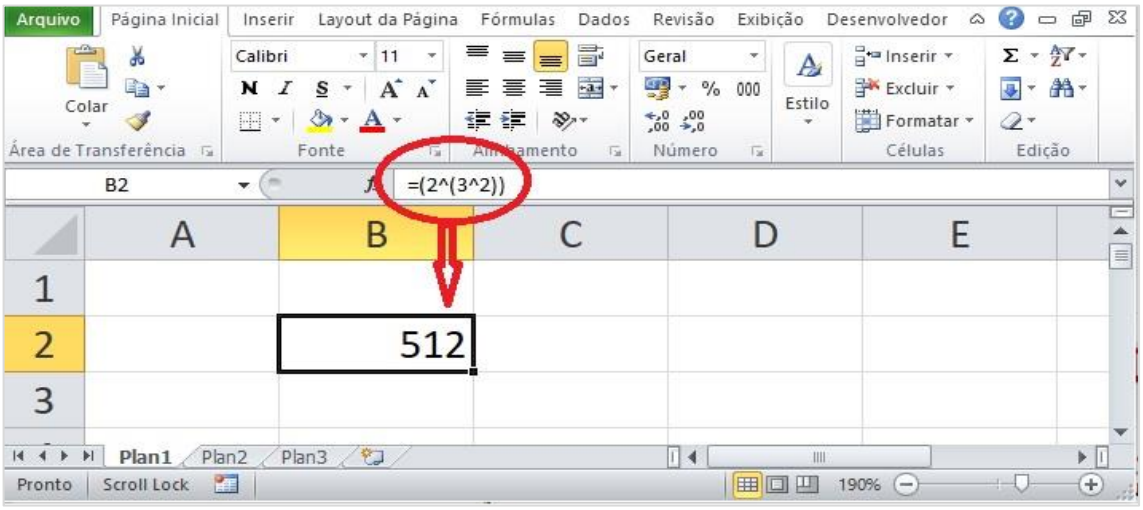
From this understanding, regarding the use of parentheses, it is understood that there is an ordering in terms of the resolution of the mathematical items that, regardless of the presence or not of the parentheses themselves. Thus, sequential ordering must occur for a correct resolution and, when it is not explicitly stated, any reliable system must automatically include it to reach a satisfactory result. It is also noted that:

> In numerical expressions, powers and square roots are taken before multiplications and divisions, and these before additions and subtractions. In addition, parentheses, brackets, and braces must be respected. (Centurión e Jakubovic, 2015, page. 40)

However, it is possible to realize in the following examples that, in the different spreadsheets available on the market, there are not only differences in the way of performing complex mathematical calculations, but there are also differences between the theoretical forms and the formulas adopted by the systems themselves to solve these mathematical equations.

In this example (Figure 01), we have the equation involving power over power, it is possible to observe that, in the expression “2” raised to the power of “3” raised to the power of “2”, already in the first spreadsheet observed, the occurrence of the first conceptual error was identified, whether or not the user enters the brackets, the correct mathematical formula would force in the adoption of a logical sequence, to first calculate the power of “3” raised to “2”, to then calculate the power of “2” raised to its result.

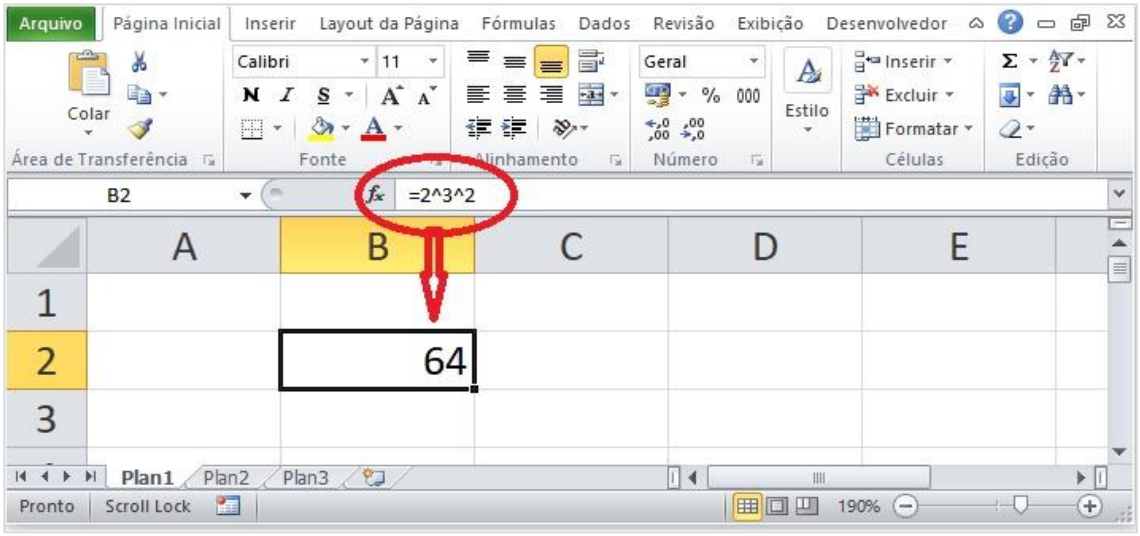
FIGURE 1
EQUATION =(2^(3^2)) - APPLICATION 01



Source: Prepared by the authors

However, as can be seen in the same spreadsheet (Figure 02), when the parentheses are removed from the equation, the application 01 erroneously understands that these are different calculations and, therefore, with different results when calculating the expression with and without the parentheses. In other words, in the first case (Figure 01 with parentheses) the expression "2^(3^2)" has as correct result "512" and the expression "2^3^2" (Figure 02 without parentheses) shows as result "64", which is a conceptual error, since the existence or not of the parentheses does not change the order of the equation resolution.

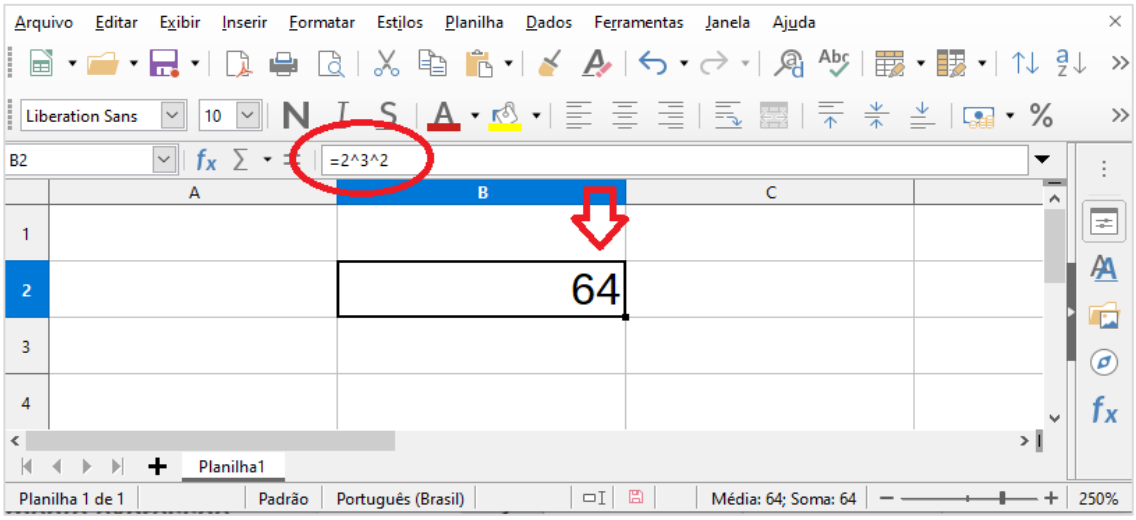
FIGURE 2
EQUATION =2^3^2 - APPLICATION 01



Source: Prepared by the authors

This same conceptual error was identified in the second application, this new tool observed (as highlighted in Figures 2 and 3), demonstrates a logical trend in the way in which spreadsheets deal with compound operations, especially in the logical ordering to solve the proposed calculations.

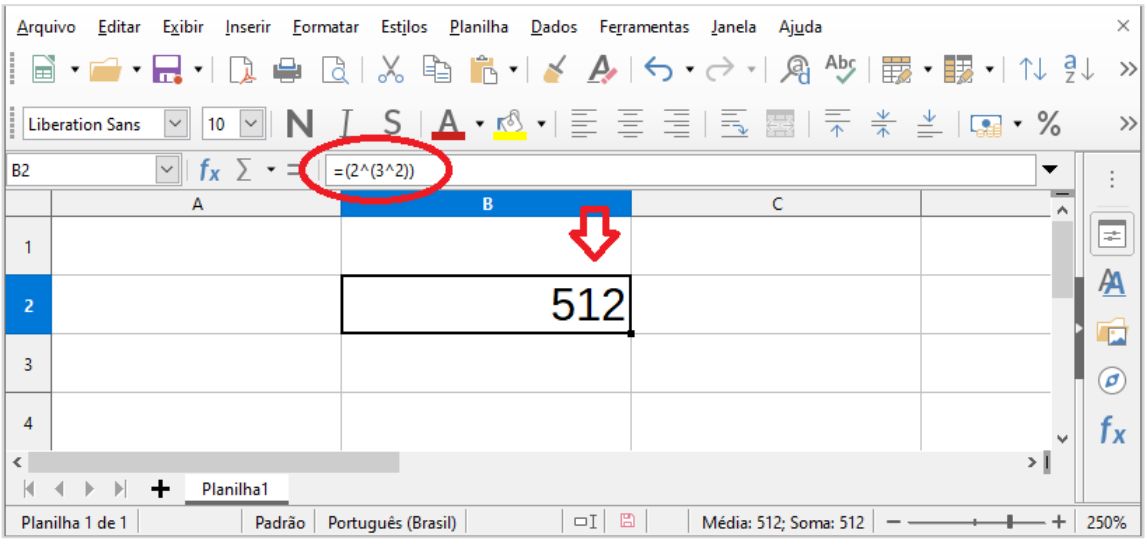
FIGURE 3
EQUATION =2^3^2 - APPLICATION 02



Source: Prepared by the authors

It is conceptually reinforced that the purpose of the existence or not of parentheses in an equation is to isolate and order for the execution of calculations, being a facilitator of the calculation, as already defined by Centurión and Jakubovic (2015) and reinforced by GCF Global (2020) in their technical publications.

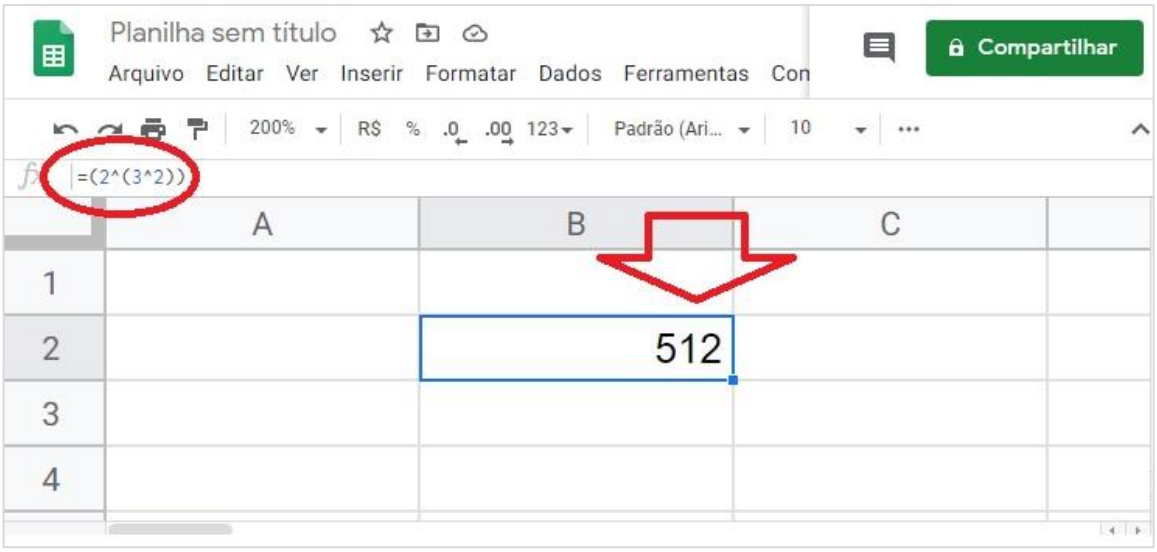
FIGURE 4
EQUATION =(2^(3^2)) - APPLICATION 02



Source: Prepared by the authors

It should be noted that the error identified did not occur in the third application tested (as highlighted in Figures 05 and 06), which demonstrates not only the error, but also presents a significant difference in the tools available on the market that, even sharing similar theoretical and technological bases, the spreadsheets tested (Applications 01, 02 and 03) have different cores of logical and mathematical operation (calculations).

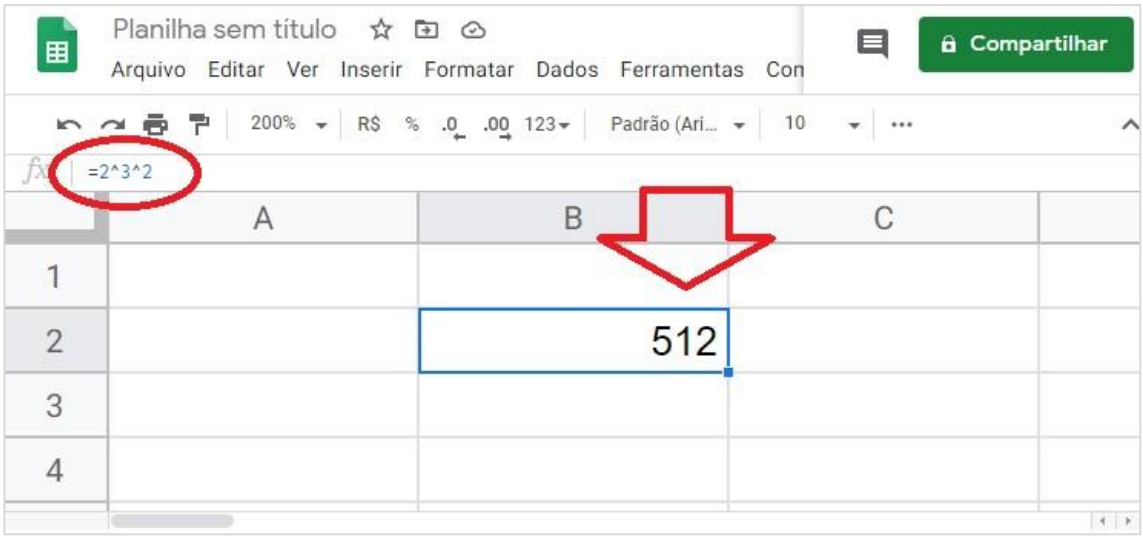
FIGURE 5
EQUATION =(2^(3^2)) - APPLICATION 03



Source: Prepared by the authors

In these cases, both the expressions “2^3^2” (Figure 06) and “2^(3^2)”, result in “512”, which is not only correct (based on mathematical logic), but demonstrates the application of theories consistent with the realities studied here, regarding the correct priority and sequence in the execution of complex expressions.

FIGURE 6
EQUATION =2^3^2 - APPLICATION 03



Source: Prepared by the authors

It should be noted that the work of the authors in relation to the identification and tracking of bugs, inconsistencies, mathematical errors and logical errors in spreadsheets is continuous and ongoing, which presents an even more worrisome scenario. Why, despite the fact that its developers are already aware and have been notified, countless errors identified in electronic spreadsheets are still present with the evolution of updates and software versions available on the market?

> Through the examples shown, and consequently the inconsistencies contained in them, it is observed that, in addition to not transferring confidence with respect to the marketed technologies, these tools, as well as many others, do not guarantee the non-existence of fundamental errors, and there may even be errors with greater severity than those proposed in this chapter, these structural flaws with respect to the mathematical and logical foundations are hidden in the computerized systems themselves, being possible their identification only by individuals who possess specific foundations and knowledge, in this case, logical and mathematical knowledge that denounce the respective non-conformities. (Medeiros e Gonçalves, 2018, page. 57)

In this regard, it is recalled through the studies of Gonçalves and Medeiros (2015) the existence of other errors in spreadsheets persist through versions and updates, as well as the treatment of different mathematical expressions as if they were the same (the famous case of “$-2^2 \neq (-2)^2$”). These errors can be observed when applying the expressions “-2^2” and “$(-2)^2$” in a spreadsheet. It should be observed that the expression “-2^2” is different in essence to the expression “$(-2)^2$”, therefore with different results, but that in the spreadsheets they are treated as if they were the same mathematical expression which in essence is the opposite of what is presented in the expressions “2^3^2” and “2^(3^2)” discussed in this chapter and which are the same mathematical expression and therefore have the same result, since in the case “$-2^2 \neq (-2)^2$” the existence of the parenthesis changes the result precisely by defining new order in the sequence of calculation.

FINAL CONCLUSIONS

Making a distinction between different logical, mathematical or arithmetic expressions, knowing the origin and application of certain types of data in a simulated environment, knowing the correct construction of formulas and calculations are concepts that allow the user to correctly evaluate the data presented by tools and applications that many consider reliable, or rather, need to be reliable. However, there is an increasing reliance on systems and tools whose initial objective is the support and socio-technological development of our lifestyle.

> By understanding this conceptual basis, it is possible to observe the presence of technology penetrating contemporary society in numerous situations, whether in the prosthesis that restores movement to an amputated patient, or in the urbanistic mechanisms adopted for the infrastructure of Brazilian municipalities, such as transportation, security, leisure, water, light and sanitation, or even, all this is conceptually considered technology, and it should only be understood that these technologies do not necessarily have to be innovative, cybernetic, digital or even futuristic, it is enough that they have in their conception the provision or expansion of a need. (Medeiros, 2017, page. 115)

We increasingly depend more and more on companies that develop systems and applications that make our daily lives easier, relieving us of the need for certain skills or complex reasoning so that society can devote more time and attention to other factors. However, the lack of need in the development of these "expendable" competencies is precisely what causes the aforementioned technological dependence. The logical flaws, errors and inconsistencies that have been presented in the handling of spreadsheets are found in elementary synthesis, that is, they are basic knowledge acquired in traditional training, as for example in the case of operations involving powers and the use of parentheses, which are, or should be, developed in the 7th grade school curriculum, in the subject of mathematics (Gonçalves and Medeiros, 2019).

Thus, since we are dealing with basic logical knowledge, involving mathematical operations that permeate from the simplest operations in electronic spreadsheets to the most complex data processing, refinement and debugging systems, especially statistical, logistical, and accounting ones, it is possible to glimpse the consequences that this type of logical inconsistency could cause in a society deliberately dependent on technological factors.

As previously mentioned, this chapter is a continuation of the studies and research by the authors on the topic of "fragilities, inconsistencies and errors involving spreadsheets", therefore, it is not limited to looking at the possible socioeconomic impacts only from the examples presented here, since in this section, due to its limited content, it was not possible to go deeper into each element identified as an error. However, it is already possible to see that these items are potentially detrimental to the use of these tools at the strategic level, given the risk that fundamental operations do not include certain calculations and that users are not properly qualified to identify, correct or circumvent these errors in favor of a real, reliable, and useful result for management.

It is stated for the record that it is not the intention of the authors to discredit or attack a particular tool to the detriment of other more robust ones; it is a warning for developers to take a more careful, judicious and well-founded look at issues involving fundamental mathematical operations, as well as the need to review the training of many users who, given the colossal technological dependence, no longer have the knowledge, skills or even the minimum attitudes to be protagonists of the necessary solutions for this topic. After all, the more dependent a user becomes, the more confidence he/she will have in the result presented, regardless of whether it is correct or not, since for those who only know what is wrong, what is right is doubtful.

But not all is criticism, in this work it was possible to observe that of the three applications tested with identical characteristics and purposes, one of them already had at least one of the errors corrected, a factor that had not occurred in the history of the authors' research, which demonstrates an initial concern on the part of the company, already differentiating it from the others with respect to spreadsheets.

This is the invitation to reflect, if primary errors like these are occurring in our apps and we are not able to identify them, where is the major flaw in the system? Is it in the poorly developed application or is it in the user who relies exclusively on the application and no longer has the critical sense to evaluate the results, albeit randomly and by sampling?

REFERENCES

Centurión, M., & Jakubovic, J. (2015). *Matemática nos dias de hoje, 7º ano: Na medida certa* (1st ed.). São Paulo: Leya.

GCF Global. (n.d.). *O uso dos parêntesis*. Retrieved from https://edu.gcfglobal.org/pt/somar-e-subtrair/o-uso-dos-parentesis/1/

Gonçalves, R.A., & Medeiros, J.d. (2015). O ensino da matemática na contemporaneidade e o impacto das planilhas eletrônicas de cálculo. In *Anais do XII Congresso Nacional de Educação – EDUCERE*. Curitiba: PUC/EDUCERE. ISSN 2176-1396

Gonçalves, R.A., & Medeiros, J.d. (2019). CAPÍTULO 14: O Ensino da Matemática na Contemporaneidade e o Impacto das Planilhas Eletrônicas de Cálculo. In *Educação no Século XXI* (Vol. 14 – Matemática, pp. 119-126). Belo Horizonte - MG: Editora Poisson.

Medeiros, J.d. (2017). A Concepção Tecnológica em Ambiente Acadêmico. In *Tecnologia, Currículo e Formação de Professores no Mercosul-Conesul* (pp. 113-132). Curitiba: Editora CRV.

Medeiros, J.D., & Gonçalves, R.A. (2018). Aplicações Tecnológicas em Ambiente Acadêmico: Um Olhar Sobre O Uso De Planilhas Eletrônicas E Seus Impactos Sócio-mercadológicos. In R. Carrara, R. Martins, & M.A. Orth (Org.), *Educação e Tecnologia na América Latina* (1st ed.). Florianópolis, SC: Contexto Digital Tecnologia Educacional.