Educação & realidade

Dicumba Methodology - conjectures and potentialities in the teaching of Chemistry: a descriptive statistical analysis

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ABSTRACT – Dicumba Methodology - conjectures and potentialities in the teaching of Chemistry: a descriptive statistical analysis. This article aims to present and substantiate the conjectures of the Dicumba methodology from a descriptive-statistical analysis about the activity which took place in 7 classes of Basic Education. At the end of the activity, students answered an online questionnaire with 8 assertions on a 5-point Likert scale and 2 discursive questions, interpreted using a mixed approach. Statistical analysis was based on the t-test and the Kruskal Wallis test, assuming the alternative hypothesis for $p < 0.05$. At the end, there is, statistically, an effect of the gender category on assertion H, of the age category on assertion E and of the school year category on the statement F.
Keywords: **Chemistry Teaching. Dicumba. Statistical Analysis.**

RESUMO – Metodologia Dicumba - conjecturas e potencialidades no ensino de Química: uma análise estatística-descritiva. Este artigo objetiva apresentar e fundamentar as conjecturas da metodologia Dicumba a partir de uma análise descritivo-estatística sobre uma atividade realizada em 7 turmas da Educação Básica. Ao final da atividade, os alunos responderam um questionário online com 8 assertivas em uma escala Likert de 5 pontos e 2 questões discursivas, interpretadas de forma mista. A análise estatística baseou-se no teste t e no teste de Kruskal Wallis, assumindo a hipótese alternativa para $p < 0,05$. Ao final, há, estatisticamente, efeito da categoria gênero na assertiva H, da categoria idade na assertiva E e da categoria ano escolar na assertiva F.
Palavras-chave: **Ensino de Química. Dicumba. Análise estatística.**

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Introduction

In recent years, different researches in the field of Chemical Education have been developed in relation to the concepts and movements established for the qualification of teacher education, teaching and learning processes, essentially emphasizing neuroscience actions, contextualization, interdisciplinarity and, among others, the use of digital technologies and active methodologies (Maldaner, 2000; Schnetzler, 2002; Bedin, 2021). However, although these studies demonstrate the need for the active role of the student in the processes of construction and meaning of knowledge, as well as in the access and dissemination of information, in the Brazilian context, a hegemonic teaching practice based on the pedagogy of transmission, considering the teacher as the center of the entire process (García-Perez, 2000; Lima, 2012).

In this perspective, essentially in the teaching of chemistry, it is understood that the development of teaching and learning processes with a focus on the scientific and conceptual dimensions promotes a boring, decontextualized and often inappropriate teaching for the ethical and civic education of the student, considering the subjective dimensions of this process. Thus, to overcome the negative consequences of this pedagogical design, there is a strong movement to the detriment of teacher qualification with a view to enhancing the teaching and learning processes, which emphasizes the use of active methodologies and the promotion of a transformative education centered on the student from the problematization of its own context. This movement is important because, paraphrasing Nicolaides (2012), one of the most powerful instruments to change society is education, and the redefinition of teaching action, considering innovative pedagogical practices, is the best way to qualify education.

In this contribution, it is understood that active methodologies, in addition to favoring the autonomous and critical participation of the student during the development of actions established in the teaching and learning processes, aim to provide teachers with a moment to think and reflect on their practice, so that they can integrate and relate knowledge. Furthermore, the use of active methodologies in chemistry teaching provides the teacher and students with the collective construction of knowledge, as well as enhancing the formation of a reflective, active and collaborative attitude in them. After all, active methodologies provide different ways of teaching and learning, and teaching is a movement that enables beneficial and meaningful learning for the student through the use of appropriate procedures (Centra, 1993), where appropriate learning situations are created; organizing and enhancing these situations is what engaged teachers effectively do (Braskamp; Ory, 1994). Among the different active methodologies used in teaching chemistry, the Dicumba (Universal-Bilateral Cognitive Development of Learning) methodology stands out, which aims to develop the teaching and learning processes through research as a pedagogical principle, centering learning on the student as a person.

Thus, considering the aforementioned context, the objective of this article focuses on presenting and substantiating the conjectures of Dicumba methodology from a descriptive-statistical analysis on the students' notes in relation to Dicumba's potential in chemistry teaching. This objective derives from the following questions: i) does the use of Dicumba in Basic Education provide students with a socio-scientific identity?; and, ii) statistically, is there a significant difference in the subjects' assessment regarding the application of Dicumba? Therefore, this article, through a critical design of data interpretation and analysis, aims to support the Dicumba teaching methodology from its developments in the teaching of chemistry, pointing out the importance of teaching being developed through research as a pedagogical principle, as well as the need for a significant break in the school curriculum, so that it is thought out and developed based on the interest and curiosity of the student.

Dicumba's Conjectures and Trajectory for Pedagogical Action

To describe the Dicumba methodology, validating its theoretical bases, support was sought in the writings of Bedin (2020) and Bedin and Del Pino (2018; 2019a; 2020a), since these authors are the creators of the methodology, and have developed research with and about Dicumba in the area of chemistry teaching since 2017. Dicumba, as a research movement for learning in the chemistry teaching, provides for the student an active moment of knowledge connection, emphasizing the relationship between the scientific and everyday life, and for the teacher the perception of duty in relation to both scientific and pedagogical improvement.

This process, established at Dicumba, is possible because the student defines a research topic that is interesting for him and, based on universal research, the teacher makes relationships with chemical science, prompting the student to carry out new research in order to the concepts emerging in this can then be developed in the classroom as a principle of social, scientific and conceptual formation in the student. In this contribution, it can be seen that Dicumba enables the realization of an adaptation in the plastered curriculum, urging the teacher to develop the minimum contents of chemical science based on the interest and curiosity of the student. Corroborating, Rangel et al. (2019, p. 2) argue that using "research in chemistry teaching is an excellent way to enhance the teaching process in public schools, as this science, [...] needs to be developed in the light of the subjects' interest, curiosity and context".

Thus, from the conceptions of Demo (2009), it is understood that when the student develops the research in a process of self-construction and reconstruction, the research provides and supports the formation of the subject in an active way of constructing their own autonomy. In this field, Bedin (2020, p. 238) states that the "teacher must exhibit the chemical science in a different way, urging the student to build concepts based on their reality, so that they perceive scientific knowledge in their daily lives, so he can use and improve his surroundings and his quality of life". Furthermore, it is understood that Dicumba is an expressive way for the student to understand the chemical science within their reality, specifically knowing the scientific concepts and contents that are directly related to what they are interested in.

Referring to the Dicumba, it makes that it enables Learning through Student-Centered Research (LSCR), an action that "approaches a concept that defends the act of researching as an integral and important part of the performance of contextual and problematizing knowledge of the student for the development of the curriculum contents of chemical science" (Bedin; Del Pino, 2018, p. 341). In this bias, it is understood that students develop an efficiently active and critical identity, as they are enabled to participate actively in the classroom, sharpening their senses to research, solve problems, create hypotheses and, among other actions, write and argue scientifically. Thus, it is clear that students have a significant gain when the teacher works with the Dicumba methodology in the light of the LSCR, as conceptual understanding comes from a process that begins with a topic of self-interest, providing them with the mobilization of skills and attitudes, in addition to skill development.

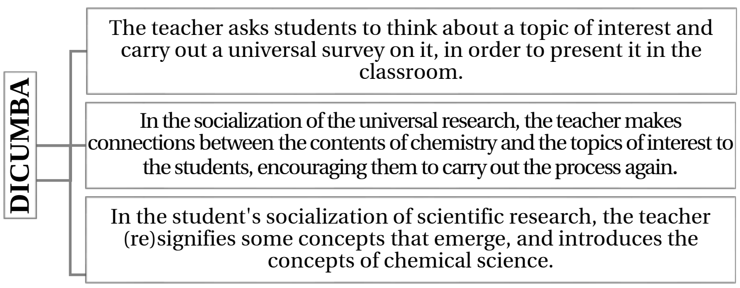
In this perspective, it is possible to affirm that students, in construction and self-learning activities, such as the Dicumba methodology, dedicate themselves with greater intensity to the act of interpreting and the writing process, constituting scientific knowledge from the very action of arguing; this design is expressive because it allows the student, in addition to the action of self-knowledge and learning about their interests, to learn within the necessary time-space, based on their learning characteristics. In other words, Dicumba is an active methodology that aims to provide the student with a differentiated teaching process, where he, in addition to being the author of the construction of his own knowledge through research, means information based on a specific theme. This movement is essential in the chemistry teaching from Dicumba, because "[...] research seeks in practice the renewal of theory and in theory the renewal of practice, education finds in knowledge the crucial lever of innovative intervention" (Demo, 2002, p. 9).

Reinforcing the above, Bedin and Del Pino (2020b) state that the learning process from the LSCR depends, among several elements of constitution and training, on a pedagogically humanist, exultant and empowering meaning, as it must be efficiently promoted centered on the student as a person and through truly didactic actions. This aspect is important in the development of teaching and learning processes because "person-centered didactics emphasizes the teacher and the student as people and their relationship exists in a climate of mutual respect, where it is up to the teacher, basically, to give the student favorable conditions to develop their intellectual and affective potential" (Rogers, 2001, p. 52), considering the promising engagement of the subject.

As a result of the above, Bruner (2006) believes that the representations that subjects have about their context/world must be touched upon through the insertion of active methodologies, as is the case with Dicumba. In addition, for the author, when these representations are explored, it becomes possible to identify the interface between the individual and the social, which allows freedom to understand the way of thinking, as well as the interests and desires of the subject, considering a given culture. In this regard, it is understood that Dicumba enables the action of understanding the social space of the subject, making him research, understand and argue about it, so that he can work on the scientific of science not randomly, but focused on the context and in the interest of the student as a person. In summary, through Dicumba, there is an inversion of the learning process that occurs in the vast majority of schools today, as the development of chemistry teaching occurs from the association of meanings that are part of the student's interest and are present in its context, rather than using the student's context to exemplify the concepts of chemical science.

In this perspective, it is believed that Dicumba, among other actions, enables the teacher, in the art of guiding and enhancing the learning process, directing and developing contextualized teaching based on the student, and not via generically formulated questions. This process makes the subject concentrate the actions in the research centered on himself in a specific and directive process, which grants him the criticality and reflection in the production of scientific knowledge linked to his world. To expose the spiral path of dialectical research of the Dicumba methodology, Bedin and Del Pino (2018, p. 341-342) were adapted from the steps and hypothetical processes for its development, as shown in Figure 1.

Figure 1 – Hypothetical path for the development of the Dicumba



Source: Authors (2023).

When interpreting Figure 1, it is possible to see that the development of scientific content and concepts in the classroom only occurs after the student's research, as well as after his choice and presentation of concepts. In addition, it is possible to show that the subject is valued as a person, letting him expose his ideas and conceptions about what really interests him to, later, develop scientific research that will support the development of chemical science concepts. Thus, from a constructivist conception of teaching, as well as a pedagogical improvement related to the principle of globalization, the teacher, by adding the elements of dialogue, meaningful learning and active interaction of the student in the learning process, provided the development of Dicumba in the classroom.

Thus, in the first class, in the midst of investigative dialogue, the teacher asks students to think about a topic of interest, and that in the next class (a week later) they bring some ideas related to this topic to be exposed to the class. Given the time, in the second week of class, each student presents their research topic and comments on it to the class. At this time, the teacher, in addition to listening to the students' comments on the themes, where the interest and curiosity of the subjects is shrewdly emphasized, letting emotion surface, asks small questions about the topic of interest, which were directly related to the scientific contents of chemical science.

After the week, the teacher delivers to each student the scientific questions he elaborated based on the topic of individual interest. That is, for each topic, during the presentation, the teacher determines scientific directions in the light of chemical science, in order to enable each student to carry out scientific research that, in addition to addressing the topic of curiosity, can highlight the contents and the concepts of chemical science. To carry out the scientific research by the student, the teacher needs to suggest a time of three weeks, being reinforced that in the next class, after these, each student must present their scientific research. This process is enriching because it allows the student to experience new concepts and, mainly, to return to the contents of chemical science already experienced during their high school education. After all, as Dicumba instigates research based on the student's interest, the guiding questions asked by the teacher are comprehensive enough to address the concepts worked on chemical science since the 1st year of high school.

In this process, it is understood that the student will research significantly to answer the teacher's questions, since the answers to the questions will not be found directly on the Internet; they must be organized and elaborated based on the student's understanding of the fusion between the scientific concept and his topic of interest. It is a process of reformulating ideas and hypotheses that the subject holds about the object under study, since the questions are new and specifically address the student's theme and chemical science. Thus, it is understood that via Dicumba the “student develops a more critical and reflective identity with their reality in the light of chemistry teaching” (Bedin, 2020, p. 239), since the student will need to find multiple information, to decode and organize them into ideas, exchanging experiences and mobilizing skills to assimilate and accommodate the constituted theoretical knowledge.

In this regard, Moraes, Ramos e Galiazzi (2012, p. 10) state that research in the classroom "[...] can be represented as a dialectical cycle that can gradually lead to increasingly advanced ways of being, understanding and doing. The main elements of this cycle are questioning, reconstruction of arguments and communication". In corroboration, Bedin (2020) reflects that investigation through questioning is the first step in the process of learning via Dicumba; as a result, the next step is to establish an argument. At this stage, students can use new ways to articulate knowledge to understand that knowledge can be reconstructed through oral and written dialogue. In this order, knowledge is socialized so that it is possible to redefine it in detail from various angles; therefore, it is evident that Dicumba provides a significant way to elucidate chemistry in the issues that are crucial for the students.

Thus, after the development of the entire activity in the light of Dicumba, students present their scientific research and, in the middle of the presentations, bring specific contents and concepts of chemical science, which must be taken up and (re)signified by the teacher, emphasizing those that will serve as content drivers for subsequent classes. Furthermore, at the end of the presentation of the students, the teacher emphasizes that he would like to know the individual opinion of each one regarding the activity developed and, as the process follows an ethical parameter of willingness and freedom to respond, the teacher provides a Link in the class WhatsApp group, so that those who are interested and have time to answer the proposed questions.

Furthermore, as a matter of curiosity, Chart 1, based on the experience with the Dicumba methodology in a 3rd year high school class of Basic Education in a Brazilian public school, presents seven examples of themes chosen by the students and their chemical directions performed by the teacher, in order to understand what is important and interesting for the student and how the teacher directed him to the chemical science.

Chart 1 – Topics of interest to students and chemical directions

Topic	**Chemical Directions**
Feminism	History and Philosophy of Science. Female Nobel Laureates.
Cotton Candy	Production and chemical compositions. Effects on the organism.
Sex	Hormones released in the sexual act. Structures, properties and functional groups.
Electronic Sports	Release and effects (high and low concentration) of adrenaline in the body. Chemical structure, properties and functional groups of adrenaline.
Soccer	Causes of the cramp. Properties and structure of the compounds present in Gelol (analgesic cream).
Breast Milk	Chemical composition and properties of colostrum.
Tattoo	Pigments present in inks. Structure, composition and properties.

Source: Research methodology Focus.

Seeking to significantly elucidate the research perspective of this study, the methodological approach of mixed research methods was used, in order to relate common elements between the social sciences and the phenomenon studied, in light of producing multifaceted considerations in relation to it. Thus, the development and nature of the research are based on mixed methods, where, in addition to respecting the rigor of procedures and the technique of the quantitative and qualitative approach, it was sought to base and fulfill the aspects that qualify, in a methodological perspective, the mixed approach. In this design, according to Creswell (2010), some aspects that effectively qualify the research in the mixed approach should be prioritized, such as: i) the distribution of research time; ii) the attribution of value to data; iii) the data combination process and; iv) the theorization of the study.

Considering the first aspect, which is related to the distribution of time, in which the moment of collection of quantitative and qualitative data is assumed, it can be said that these were collected sequentially, that is, concurrently with the end of the activity with no difference of level. Regarding the second aspect, which considers the attribution of value to the data collected, it is judged that their importance derives from the quali-quantitative relationship, that is, the weight in the analysis and interpretation of these data was not determined by any type of strategy, but in an equal way the data analysis is presented, emphasizing a qualitative question before the quantitative one. Thus, it is necessary to state that based on the qualitative data, a quantitative discussion is evidenced. This step was important to emphasize the third aspect, which refers to the process of combining data, which are merged and not dispersed and visualized individually. Therefore, as the data are integrated, since they were collected concurrently, the qualitative analysis, through a count and a statistical approach, was derived from the quantitative analysis (Creswell, 2010). Finally, by way of the last item, which reflects on the theorization of the study, it can be stated that there is a greater perspective of theorization based on the interaction of data, so as to present substantial results.

Units of Analysis

The case under study, investigated here, considers the participation of 152 high school students; a group of subjects that make up 7 classes of Basic Education (4 classes of the 2nd year of High School and 3 classes of the 3rd year of High School) from a public school in the city of São Leopoldo, a city adjacent to Porto Alegre, capital of the State of Rio Grande do Sul, Brazil. The specificity of this study consists in the fact that students actively participated in the development of actions adopted within the Dicumba teaching methodology. Therefore, the research focuses on the analysis of the students' notes regarding the potential of the Dicumba methodology in chemistry teaching and, in particular, in their socio-scientific training.

The application and development of activities organized in the Dicumba teaching methodology took place as described in Fig. 1, considering a duration of 6 weeks, being fully developed in the periods of the chemistry discipline, in the second half of the year 2019. It should be noted that the development of the Dicumba methodology, despite having been carried out in a similar way in the seven classes, followed the specificities and singularities present in each one.

Construction and Data Collection Technique

For the construction and collection of data, online collection via a questionnaire prepared in Google Forms was prioritized. The questionnaire was sent to the students through the class' WhatsApp groups via Link right after the activity was completed. The questionnaire had eight statements referring to the activity performed, as well as two questions that probed the profile of the subjects: gender, age and school year. It should be noted that the Google Forms platform is expressly significant for online data collection, as when the questionnaire is answered, the data is stored in the cloud, enabling downloading it in an Excel spreadsheet. Furthermore, it is noteworthy that the eight statements made available in the questionnaire were organized in the form of a Likert scale, with five degrees of agreement, which range from 1 to 5, with level 5 showing the highest agreement.

At this point, it should be noted that students were invited to participate in the research of their own free will, being informed that, upon ethical issues in research with human beings, they should sign a Free and Informed Consent Form (FICF), which stated that their names or any possible identifying data would not be exposed. Furthermore, in the FICF there was information that the research would not generate any burden or bonus for the students, and that they would be assisting in scientific questions related to Education, absolutely on the evaluation of the Dicumba methodology by filling out an online form.

Reliability of the Data Collection Technique

Considering the pretexts and assumptions of scientific research that address quali-quantitative characteristics, essentially in the construction and collection of data from questionnaires, it is understood that this instrument needs to be properly designed to reliably reproduce the reality in question. Therefore, for this purpose, the Cronbach's Alpha coefficient was used via SPSS software, as it expresses, through a factor, the degree of reliability of the responses, as well as the correlations between the different assertions (Streiner, 2003), such as is shown in Table 1.

Table 1 – Cronbach's Alpha Reliability Statistics and correlations

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0,824	**0,824**	**8**

Inter-Item Correlation Matrix

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
A	1,000	0,379	0,508	0,424	0,368	0,323	0,283	0,375
B	0,379	1,000	0,456	0,248	0,124	0,522	0,474	0,403
C	0,508	0,456	1,000	0,391	0,370	0,475	0,391	0,423
D	0,424	0,248	0,391	1,000	0,415	0,257	0,270	0,429
E	0,368	0,124	0,370	0,415	1,000	0,126	0,224	0,471
F	0,323	0,522	0,475	0,257	0,126	1,000	0,337	0,409
G	0,283	0,474	0,391	0,270	0,224	0,337	1,000	0,480
H	0,375	0,403	0,423	0,429	0,471	0,409	0,480	1,000

Source: Authors (2023).

Given the above, and considering that in the literature the minimum value for Crombach's Alpha to characterize a research instrument as considerably acceptable is 0.700, given that any value lower than this represents an inconsistency in the instrument, it is clear that the value of the Alpha of Crombach for the questionnaire used in this research is 0.824, which demonstrates an excellent value of data reliability, as the maximum value of 0.900 of a Crombach's Alpha proves internal consistency of the data and reliability of the instrument (Streiner, 2003).

Data analysis

For the analysis of the collected data, considering the instrument for the construction and obtaining of these, as well as that the researcher, in a clear, careful and thoughtful way, needs to unveil the collected material to demonstrate the main findings of the research (Lüdke; André, 1986), the interpretation of the statements was deductively considered in a qualitative way, based on the experience and observation in the application of the activity. Furthermore, from the interpretation performed, the deductions were analyzed quantitatively through statistics, taking into account the Levene test and the t-test, via the Statistical Package for the Social Sciences (SPSS) program. As far as the p-value is concerned, it was given importance and significance when it was less than 0.05 ($p < 0.05$).

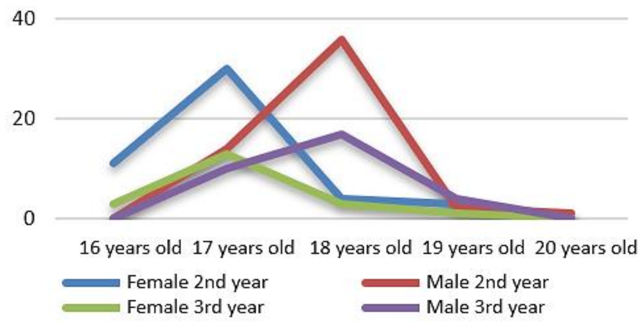
This design is important for a mixed understanding of the relationship between qualitative and quantitative data, emphasizing the means, standard deviations and the minimum and maximum degrees touched upon in each assertion. This assumption derives from the conception that it is necessary that the interpretive analysis of the data reveal implicit messages, systematically silenced themes and contradictory dimensions, deepening the inductive discussions in a subjective bias so as not to be restricted to what is explicit (Lüdke; André, 1986).

Reflections on the descriptive-statistical analysis of Dicumba's potentialities

Considering the purpose of enabling students to build scientific knowledge of chemical science based on the concepts established between what arouses their curiosity and interest in learning and the different actions to mediate the construction and meaning of knowledge, as mentioned above, the chemistry teacher at a public school developed the Dicumba methodology with seven classes. In this sense, resuming the objective of the present text, which focuses on the action of grounding the potential of the Dicumba teaching methodology from the students' notes regarding its role in the teaching of chemistry and, specifically, in the socio-scientific training of students, it was chose to analyze the data jointly, emphasizing the union of all classes. Therefore, with regard to the gender of the subjects, 75.60% (n = 100) said they were female and 34.21% (n = 52) said they were male, even with the option "other". Of this universe of 152 students, where 55.26% (n = 84) are from the 3rd year of High School and 44.74% (n = 68) are from the 2nd year of High School, 9.21% (n = 14) is 16 years old, 44.08% (n = 67) is 17 years old, 39.45% (n = 60) is 18 years old, 6.6% (n = 10) is 19 years old and, finally, 0.66% (n = 1) is 20 years old.

In summary, Graph 1 shows all research participants, considering gender, age and year of high school in a correlated manner.

Graph 1 – General data of survey participants



Source: Authors (2023).

In reference to the qualitative analysis of the assertions, considering a deductive interpretation of them, based on the degrees of agreement indicated by the subjects, students believe that Dicumba allows them to learn chemistry through an activity that provides them with the action of choosing a subject of interest and curiosity to research, as well as granting them scientific learning through motivation and desire to investigate something of their own interest. Thus, it is understood that the methodology provides the student with a different way of learning, making them an active subject of the learning process itself with the guidance of the teacher. In this line, Brito and Campos (2019, p. 373) state that in the active methodology "students together and in a horizontal relationship with the teacher, use resources and techniques that stimulate the development of new and significant learning". Therefore, Dicumba enables expressive learning because scientific knowledge of chemical science emerges from a subject that the student already has prior knowledge, enhancing the reinterpretation of information, the interaction of knowledge and, therefore, the acquisition of knowledge.

Therefore, there is a greater motivation in relation to learning, especially chemical science, considered by many students and teachers as something difficult and abstract to understand, as it presents specific codes, formulas and calculations, which makes it abstract enough for the understanding of most subjects. Thus, it is understood that Dicumba provides the student with a moment of individual learning, when he researches and writes to solve problems and reach hypotheses, and also a moment of collective learning, when the subject dialogues with the teacher and socializes with colleagues, configuring itself in a process of teaching and learning; the "teaching and learning take place in a symbiotic, deep, constant interconnection between what we call the physical and digital world. It's not two worlds or spaces, but an extended space, an extended room, which mixes, constantly hybridizes" (Moran, 2015, p. 6).

In short, in the individual learning process, when the student writes, going through an exercise of decoding ideas, organizing thoughts and writing knowledge and concepts, it is believed that some conceptual challenges exert considerable influence on universal and scientific conceptions of students, which impacts the practice of research writing and provides them with different sensations of discursive formation of their research interests, inquiring, building and articulating positions for themselves within these fields (Aitchison; Lee, 2006). Learning through research, therefore, is an opportunity to promote cognitive maturation and the development of students' potential, in particular those related to the search, analysis and interpretation of information, as well as the solution of problems emphasized in relation to scientific content (Romo et al., 2016). Hence the need to consider research and its derivations as ways to generate investigative skills and abilities in the context of Basic Education in the light of teaching and learning (Bogoya, 2005).

From this angle, it is clear that the teaching and learning processes do not occur randomly, but complement each other in a trajectory of knowledge construction; "This is an activity that involves the engagement of students and requires that teaching be organized according to the skills to be acquired" (Saint-Onge, 2001, p. 123). That is, a teaching that is "beyond the assimilation of concepts or the acquisition of information, based on constructivism and providing the student with the opportunity to experience, analyze and interpret situations that enable him to form a critical-scientific spirit" (Bedin; Del Pino, 2020b, p. 5). After all, it is known that teaching is not a limitation to the act of teaching classes, but it involves a coherent and meaningful process of learning. Learning scientifically, as well as through different teaching strategies, is an ontological action that needs knowledge reconstructed and re-signified by the subject, that is, "the meaning of teaching depends on the meaning given to learning and the meaning of learning depends on activities generated by teaching" (Saint-Onge, 2001, p. 16).

No different, the subjects still understand that Dicumba differs from other teaching strategies used by teachers in the classroom, because, via Dicumba, subjects can learn chemistry in their own space-time, prioritizing different ways of learning. This action is significant for the subjects to also feel the desire to learn more and seek new information; therefore, it is understood that a teaching methodology that values student learning, regardless of place, space and intensity, is plausible for the subject to want to learn, since a group of heterogeneous students presents specificities and singularities in learning. Dicumba, in particular, presents a specific way for the subject to build knowledge from a topic that emerges from their interest, as well as enabling research as a tool capable of enabling the student to access different pertinent information, modifying and adding to its repertoire of knowledge. Furthermore, the methodology instigates the subject to want to learn more because the teacher acts as a knowledge enhancer, serving as a support for the student to mobilize skills and knowledge in the act of solving a problem, or even as a being who provides tools and information for the student to solve it.

In this perspective, Bedin (2020, p. 241) states that Dicumba is "a way to enhance the active and critical action of the subject during their basic scientific training, strengthening, in addition to specific teaching actions, the experience and curiosity of the student, the development of pedagogical practices in a collaborative and cooperative approach". This feature is possible when the student says that Dicumba allows him to seek new information, carrying out the research at different times to resolve his doubts; it is an important process in the socio-scientific formation of the subject, because it demonstrates, in addition to autonomy and willingness to research, the interest and desire to learn, not necessarily in the space-time of the classroom. It is in this way that Bedin and Del Pino (2020b, p. 7) state that "the teacher can stimulate the creativity of the student, individual or collective", asking them to develop different ways to present their research, not limited to oral or written presentation.

Furthermore, according to the subjects, the actions of learning chemistry from the freedom and responsibility to scientifically build arguments, as well as to evolve with the concepts and contents studied from the perception of their importance for their own training are also features of Dicumba. Thus, it is understandable that the methodology provides the use of different dynamic and interactive ways of learning, which give the subjects the opportunity to manipulate and interact with information, which, after being re-signified and reconstructed, allow the subject to signify their reality and, from this, modify the way of thinking, understanding and arguing. However, giving freedom and responsibility to the student, considering him as a transformative agent of the learning process itself, is an action that requires differentiated teaching and learning assumptions. That is, providing the student with individual and collective scientific evolution requires a significant dynamism in teaching practices, which are no longer focused on the teacher, but on the interaction between him and the student, as well as between them and knowledge. No different, Dicumba requires that conceptions be focused and centered on the formative process of learning with dialogue and collaboration, and not on a process of hierarchically organized content.

In this perspective, it is clear that "student learning is favored as he, collaboratively with the teacher, establishes significant relationships between what he knows (research topic) with the knowledge he does not know (scientific knowledge)" (Bedin; Del Pino, 2020b, p. 7). In this way, Dicumba can be understood as a methodology that presents biases to minimize, and even break, the dichotomy between practice and theory. It is in this sense that it is believed that Dicumba can contribute, among several other actions, to the implementation of curriculum restructuring in schools, in the sense that it is carried out from the student as a person; It should be noted that when talking about curriculum restructuring based on Dicumba, the idea of minimizing or even substituting activities already carried out hierarchically is not defended, but rather to maintain and develop them based on their emergence in the research of students.

Still, the subjects emphasize that there is the possibility of learning chemistry through Dicumba as chemical concepts are reviewed and reconstructed. In this process, it is clear that Dicumba, as a pedagogical strategy, allows, in addition to what has already been highlighted, a specific moment of support for the teaching and learning processes in relation to revisiting the contents, reorganizing information and giving new meaning to the concepts; it is an indispensable action in the qualification of educational processes, as Dicumba is a way for the subject to refresh the contents and contextualize them in other dimensions.

In this contribution, Nicolaides (2012) reflects that learning is a process that must produce the desired changes in the behavior and cognitive formation of students. Consequently, the learning methodologies used in classrooms are important and relevant for understanding the concepts taught, encouraging students to build more concrete thinking. Therefore, it is understood that learning occurs when perception is obtained, and when processes are understood; in short, when the dialogic-cognitive interaction took place between the teacher and the students and between the students and their peers. Therefore, based on the statements by Lunenberg and Volman (1998), it is clear that learning is a movement that requires changes in the teacher's action; the teacher must focus on the role of guiding the students' active learning process.

Finally, based on the statements by Bellardo et al. (2021, p. 348), it is believed that the Dicumba teaching methodology is important and significant insofar as it enables the student to "identify and interpret phenomena, build and organize knowledge, create and communicate hypotheses", since these "those are essential actions for cognitive development". Thus, it is understood that the internalization of scientific knowledge in the lives of students in light of the practices established in Learning through Student-Centered Research is capable of making them scientifically literate. Therefore, "it is hoped that, within their own experience and peculiarity, the student is able to learn individually, authentically building their theories, communicating them and, finally, concluding them, with scientific rigor and practical utility" (Bellardo et al., 2021, p. 348).

As a result of what has been said about the placements of the students, a statistical analysis was carried out on the assertions, in order to validate them quantitatively. For this, as already highlighted, the SPSS program was used. Therefore, in the statistical analysis, the minimum and maximum scores indicated on the Likert scale are presented, as well as the mean and standard deviation for each assertion. Specifically for the Gender and School Year categories, the t-test was used, since these categories do not have more than three groups. For the Age category, which had five groups, the Kruskal Wallis test was used. Anyway, for both tests, significance was only considered for $p > 0.05$, highlighted in the tables as "Sig". That is, this research considers a probability of 5% that there is a difference between the subjects' agreements, assuming the alternative hypothesis; therefore, rejecting the null hypothesis with 95% confidence. About descriptive statistics, there is Table 2:

Table 2 – Descriptive Statistics

	Assertions	Mi	Ma	M	SD
A	Learning chemistry in my space-time, prioritizing my way of learning	1	5	4,25	1,037
B	Learning chemistry as it evolved with the concepts and contents studied	2	5	4,03	0,876
C	Learning chemistry from the freedom and responsibility to scientifically build my argument	2	5	4,05	0,958
D	Learning chemistry through an activity that allows me to choose a subject of interest and curiosity to research	2	5	4,61	0,719
E	Learning chemistry through motivation and the desire to research something that interests me	2	5	4,47	0,797
F	To learn chemistry as it was reviewed and reconstruct chemical concepts	1	5	3,78	0,998
G	Learning chemistry from the perception of the importance of the content studied for my formation	1	5	4,03	0,986
H	Learning chemistry from the desire to learn more and to seek new information	1	5	4,20	0,923

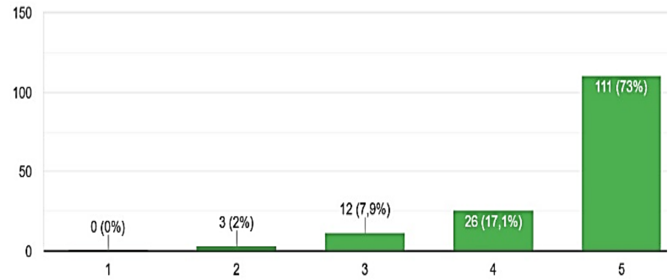
Leg. Mi = minimum, Ma = maximum, M = mean, SD = standard deviation.
Source: Authors (2023).

Observing Table 2, it can be seen a variance in the agreement scores of the subjects, these being variants from 1 to 5 for statements A, F, G and H and variants from 2 to 5 for statements B, C, D and E. Although there is a difference in the score variation, it is perceived that this is statistically small to allow for significance, since scores 1 and 2, the lowest scores on the Likert scale, are considered non-agreement scores; therefore, all assertions received degrees of agreement and degrees of disagreement. Other relevant information, presented in Table 2, is related to the means of each assertion, which are calculated by dividing the sum by the counting of notes in each score, resulting in a single value that represents the set. In this sense, in descending order of average by assertion, we have: D (M = 4.61), E (M = 4.47), A (M = 4.025), H (M = 4.20), C (M = 4.05), B and G (M = 4.03), and F (M = 3.78). Given the decreasing ratio of means, it is understood that there is no statistically significant difference between them, since the variation between the highest and lowest mean is 0.83; a significantly small number in statistical terms of mean variation; therefore, it is determined that, in general terms, there was agreement on the part of the subjects in all assertions.

In detriment of the above, it can be understood that students agree in significant degrees that Dicumba provided them with a different way of learning chemistry, as the activity allowed them to choose a subject of interest and curiosity to research and, based on this centered research, understand the objects of knowledge of chemical science through motivation and desire to research. No different, but with a lower degree of agreement, the subjects also state that Dicumba is a pedagogical strategy that provides them with learning in chemistry as they research, review concepts and reconstruct chemical knowledge. Thus, Rangel et al. (2019, p. 2) emphasize that research must be understood "as a pleasurable and enriching action where teacher and student develop it together, so that the teacher improves and the student is enriched with knowledge from their research"; in this regard, the "teacher ceases to be a knowledge holder and starts to be a learning enhancer, as the student, by himself, must be able to seek, filter and interpret information that is necessarily significant to his context and his life" (Bedin; Del Pino, 2019b, p. 1374).

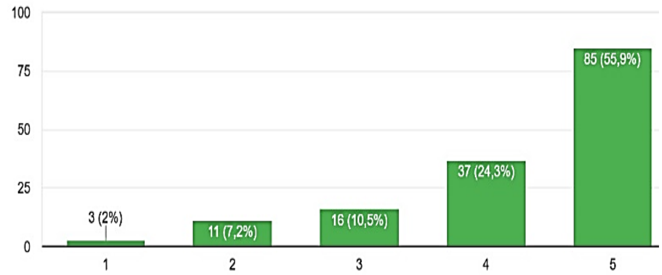
In addition, the SD of each assertion can be seen in Table 2, which was used to calculate the dispersion of the subjects' notes in each score. That is, through the SD, a distance between the values can be seen, and the greater the numerical value of the SD, the greater the distance between the degrees of appointment. In summary, it is clear that for assertion D (M = 4.61), which has the highest mean, there is the smallest standard deviation (SD = 0.719), demonstrating that there is a proximity between the scores indicated by the subjects. However, what deserves to be highlighted is assertion A (M = 4.25), which has a relatively high mean, but an extremely high standard deviation compared to the others (SD = 1.037), demonstrating that there is a significant distance between the scores appointed by the subjects. Such design can be evidenced from Figs. 2 and 3, where it is possible to notice a significant distance (dispersion) between the subjects' notes for statement A to the detriment of statement D, in which the notes are basically concentrated in the scores 4 and 5.

Figure 2 – Data from statement D



Source: Authors (2023).

Figure 3 – Data from statement A



Source: Authors (2023).

In addition, as mentioned above, for each of the assertions, the parametric t-test of independent samples was performed, considering the School Year and Gender categories, since these, in addition to not having more than three groups, have a larger number of subjects than thirty, which characterizes the use of this type of test. However, for the Age category, the Kruskal Wallis non-parametric statistical test was performed, which requires more than three groups. In general terms, the t-test provides the Levene test, which is characterized as a test for normality of variances, presenting statistical data on the agreement in the same assertion being equal or different between the subjects of the same category, in this case, between 2nd year students and 3rd year students and, later, between boys and girls. Thus, Table 3 demonstrates the Group Statistical analysis and, later, Table 4 presents the t-test of Independent Samples for the School Year category.

Table 3 – Group Statistics for School Year Category

	School Year	Mean	SD*		School Year	Mean	SD*
A	2nd Year	4,16	1,154	**E**	2nd Year	4,46	0,905
	3rd Year	3,32	0,933		3rd Year	4,49	0,703
B	2nd Year	3,91	0,926	**F**	2nd Year	3,57	0,967
	3rd Year	4,12	0,827		3rd Year	3,94	0,998
C	2nd Year	4,03	0,946	**G**	2nd Year	4,12	0,044
	3rd Year	4,06	0,974		3rd Year	3,96	0,937
D	2nd Year	4,66	0,638	**H**	2nd Year	4,19	0,918
	3rd Year	4,57	0,749		3rd Year	4,21	0,932

Source: Authors (2023).

Table 4 – Independent Samples t-Test for the School Year category

		Levene Test		*t-Test*		
		F	**Sig.**	***t***	**Sig.**	**AD***
A	EVA*	5,139	0,025	-0,943	0,347	-0,160
	EVNA *			-0,922	0,358	0,160
B	EVA	0,777	0,380	-1,456	0,148	-0,207
	EVNA			-1,439	0,153	-0,207
C	EVA	0,039	0,843	-0,192	0,848	-0,030
	EVNA			-0,193	0,844	-0,030
D	EVA	1,389	0,241	0,769	0,443	0,090
	EVNA			0,777	0,439	0,090
E	EVA	3,256	0,073	-0,247	0,805	-0,032
	EVNA			-0,241	0,810	-0,032
F	EVA	0,058	0,810	-2,285	0,024	-0,367
	EVNA			-2,293	0,023	-0,367
G	EVA	2,653	0,105	0,953	0,342	0,153
	EVNA			0,942	0,348	0,153
H	EVA	0,127	0,722	-0,153	0,879	-0,023
	EVNA			-0,153	0,878	-0,023

Sub. EVA: Equal variances assumed; EVNA: Equal variances not assumed; AD: Average Difference.
Source: Authors (2023).

Considering what is shown in Table 3, it is possible to see the description of the data in relation to 2nd year students (n = 68) and 3rd year students (n = 84), mainly regarding the mean and standard deviation for each assertion. As highlighted, instead of Table 3, Table 4 was plotted, which presents the t-test for equality of means and, also, Levene's test for equality of variance, present in the first column. Levene's test has as the null hypothesis that there is equality of variance between the data, with $p > 0.05$, and the alternative hypothesis that there is no equality of variance, reflected by the value of $p < 0.05$. Thus, when observing the representative column of Levene's test in

Table 4, for each of the assertions, it is possible to identify that only for assertion A there is no equality of variance in the data distribution, as in this assertion there is $p < 0.05$ (Sig. = 0.025). As a result of the above, for assertion A, the second line must be analyzed, as this is the one that configures the data in which equal variances were not assumed (EVNA); therefore, in the t-test column, present in the same table and in the same line, a $p > 0.05$ (Sig. = 0.358) can be seen, characterizing equality of means for this assertion.

On the other hand, statement F, for Levene's test, shows a homogeneous variance assumed in the data (EVA), represented by $p > 0.05$ (Sig. = 0.810); therefore, the first line of interpretation must be assumed, perceiving $p < 0.05$ in the t-test column (Sig. = 0.024). Thus, it is understood that there is no statistically normality in the distribution of data regarding the subjects' means for assertion F; therefore, it can be seen from the AD column in Table 4 that, as the value is negative (-0.367), as well as due to the averages in Table 3, that the group characterized by 2nd year students has an average for this assertion lower than the average for 3rd year students. In other words, the 3rd year students more rigorously agree with the idea that through Dicumba they learned chemistry as they revised and reconstructed chemical concepts. On this fact, it is necessary to reflect that 3rd year students have a greater background of concepts and contents of chemical science, since they are at the end of high school and, commonly expected from a hierarchical curriculum, they have already studied the contents linked to Organic Chemistry, different from 2nd year students, for example.

Not unlike what was described above for the School Year category, the Statistical Group analysis and the Independent Samples test were carried out in light of the Levene test for the Gender category, as shown in Tables 5 and 6, respectively.

Table 5 – Group Statistics for the Gender Category

	Gender	Mean	SD*		Gender	Mean	SD*
A	Feminine Masculine	4,29 4,18	1,003 1,108	**E**	Feminine Masculine	4,55 4,31	0,714 0,927
B	Feminine Masculine	4,10 3,88	0,889 0,840	**F**	Feminine Masculine	3,72 3,88	1,059 0,864
C	Feminine Masculine	4,09 3,96	1,001 0,871	**G**	Feminine Masculine	4,04 4,02	1,009 0,948
D	Feminine Masculine	4,68 4,47	0,692 0,758	**H**	Feminine Masculine	4,33 3,96	0,896 0,937

Source: Authors (2023).

Table 6 – Independent Samples Test for the Gender category

		Levene Test		*t*-Test		
		F	**Sig.**	***t***	**Sig.**	**AD***
A	EVA*	0,259	0,612	0,620	0,536	0,111
	EVNA *			0,600	0,550	0,111
B	EVA	0,995	0,320	1,445	0,151	0,217
	EVNA			1,472	0,144	0,217
C	EVA	7,873	0,006	0,778	0,438	0,128
	EVNA			0,815	0,417	0,128
D	EVA	3,402	0,067	1,732	0,085	0,213
	EVNA			1,681	0,096	0,213
E	EVA	6,61	0,011	1,771	0,079	0,241
	EVNA			1,627	0,108	0,241
F	EVA	4,033	0,046	-0,93	0,354	-0,160
	EVNA			-0,995	0,322	-0,160
G	EVA	0,999	0,319	0,118	0,906	0,020
	EVNA			0,12	0,905	0,020
H	EVA	1,06	0,305	2,342	0,021	0,366
	EVNA			2,307	0,023	0,366

Sub. EVA: Equal variances assumed; EVNA: Equal variances not assumed; AD: Average Difference.
Source: Authors (2023).

Table 5 shows the descriptive analysis of the means and their standard deviations for each assertion in relation to each group of subjects for the Gender category, considering that there are 52 males and 100 females. Furthermore, as a result of Table 5, Table 6 was plotted, in which the Levene test for equality of variance is shown in the first column and the t-test for equality of means in the second column, both for each assertion. Thus, as highlighted above, a $p < 0.05$ in Levene's test is perceived for assertions C, E and F; therefore, for each of these assertions, the second line is interpreted, represented by the non-assumed equal variances (EVNA). Specifically about assertion C, which has a $p < 0.05$ (Sig. = 0.006), it can be seen in the t-test column that the equality of means is, statistically, considered normal, since it presents a $p > 0.05$ (Sig. = 0.417); therefore, it is understood that there is no difference in agreement between boys and girls regarding the idea of learning chemistry from the freedom and responsibility to build scientific arguments ($t(113.669) = 0.815$; $p > 0.05$).

Still in relation to the statistical analysis of Table 6, especially the statement E, it is noticed in the column of Levene's test $p = 0.011$; therefore, it is understood that there is no homogeneity of variance between the data, assuming the alternative hypothesis. In detriment of the above, the t-test for assertion E presents a $p > 0.05$ (Sig. = 0.108), emphasizing that there is, statistically, normality in the distribution of means, that is, the agreement between boys and girls is the same as the idea that Dicumba allowed them to learn chemistry through motivation and the desire to research something of interest (t(80.790) =

1.627; p > 0.05). Furthermore, Levene's test presented p < 0.05 (Sig. = 0.046) also for the statement F, exposing the alternative hypothesis: there is no statistically equal variance for the Gender category in this statement. Thus, when analyzing the second line of the statement F, it is noticed that in the t-test there is a p > 0.05 (Sig. = 0.322), showing that there is normality in the averages of subjects of both genders for this statement (t(120.163) = -0.995; p > 0.05).

On the other hand, despite verifying in the Levene test column a p > 0.05 (Sig. = 0.305) for assertion H, it is clear that for this assertion, specifically in the t-test column, there is a p < 0.05 (Sig. = 0.021) to the detriment of the non-normality of the variation of means. In other words, for assertion H, it should be considered that there is no statistically normal distribution of means regarding the agreement of the assertion for boys and girls. Thus, considering the first line of interpretation, since the Levene test showed a p > 0.05, it is clear that the column SD has a positive value, which, according to the means of this assertion present in Table 5, reflects that the group of female subjects (M = 4.33) agrees with greater intensity that Dicumba allowed them to learn chemistry from the desire to want to learn more and seek new information, instead of the male group of gender subject's (M = 3.96).

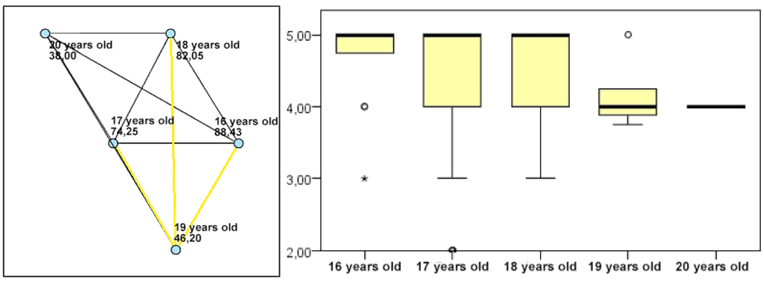
In detriment of the Age category having five different groups, and the t-test admitting an analysis of only two groups, the nonparametric Kruskal-Wallis test was performed for the Age category, as shown in Table 7.

Table 7 – Kruskal Wallis test for the Age category

	A	B	C	D	E	F	G
X^2	8,419	3,167	5,622	6,292	10,433	5,197	4,920
gl	4	4	4	4	4	4	4
Sig.	0,077	0,530	0,229	0,178	0,034	0,268	0,296

Source: Authors (2023).

Figure 4 – Pair analysis for assertion E



Source: Authors (2023).

Considering what is shown in Table 7, it is possible to verify that, for the Age category, only statement E has p < 0.05 (Sig = 0.034); therefore, the null hypothesis is rejected and the alternative hypothesis is retained, considering that there is no normality in the data distribution ($X^2(4) = 10{,}433$; $p < 0{,}05$). Thus, it is believed that the age of the subjects significantly interferes with the agreement that Dicumba provides learning in chemistry through motivation and the desire to research something of their own interest. Given the above, it was sought to perform the non-parametric Kruskal Wallis test in pairs, where it is possible, in the light of Figure 4, to identify that the non-normality of the data distribution is found between the 19-year-old subjects with the subjects 16 years old, as well as with 17 and 18 years old subjects.

Conclusion

At the end of the presentation and discussion of the data analyzed in a mixed way, considering the main objective of this article, it is believed that the presentation and justification of the findings from a critical analysis are likely to enable an understanding of the role of the Dicumba methodology in the teaching of chemistry and, mainly, in the scientific training of subjects. Thus, it is understood the importance and relevance of the Dicumba methodology being inserted in the teaching of chemistry as a way to develop it from research as a pedagogical principle centered on the student as a person, since the assertions presented in Table 2 shows expressive means of agreement on the potential of the methodology in the socio-scientific training of students.

Furthermore, on a statistical basis, and considering that Levene's test allows to verify the homogeneity of the variances, it is concluded that the variances are different in the two categories, especially for statement A in the School Year category and for statements C, E and F in the Gender category, since the significance associated with the test for highlighted assertions was less than 0.05. Therefore, as the homogeneity of the variances for the assertions was not assumed, it was chosen to use the t-test values, which showed that there are no statistically significant differences, in a 95% confidence interval, in the mean between the 2nd and 3rd year students regarding statement A and between boys and girls for statements C, E and F.

Furthermore, it is noteworthy that the t-test was interpreted, which makes it possible to understand the homogeneity of the means, individually for the assertions in which the equality of variances was perceived; therefore, for the School Year category, the independent t-test showed that, on average, 3rd year students have greater agreement in relation to statement F than 2nd year students ($t(150) = -2.285$; $p < 0.05$) and for the Gender category, the t-test showed that, on average, girls agreed more than boys regarding assertion H ($t(150) = 2.342$; $p < 0.05$). No different, the Kruskal Wallis test, from the Age category, showed that there is an effect of ages 19, 18 and 16 years on the agreement of what is stated in the statement E.

Furthermore, it is understood that one of the main objectives of education in the light of teaching practice in the classroom is to enable the student to have the autonomy to build and socialize knowledge, with the inclusion of Dicumba as a learning practice through research being a significant mechanism for this purpose, since, through this, the student researches their doubts, filters information, proposes hypotheses, organizes ideas and exposes knowledge in a non-linear and arbitrary manner, also enabling elements for the teacher to analyze and understand its own action, constantly improving himself. Thus, considering that Dicumba is a specific and adequate methodology to effectively ensure the development of skills and the mobilization of skills and attitudes in students to enrich the teaching and learning processes, prevailing its diversity, especially in relation to cultural, social, linguistic and cognitive aspects, the limitations of this study are identified, since, given the number of participants, this would be a bias to be explored.

Finally, considering the predilection for the mixed methods approach, supported by the non-parametric Kruskal-Wallis test, it is conjectured the unfolding of this research in the initial training of teachers, in an attempt to relate the parameters used in this work, proposing the reapplication of the activity and the investigative form in order to assess possible evolution of the reflections pointed here. Furthermore, given the possibility of replicating Dicumba in initial teacher education, it is worth considering the progress of this research in an investigation that centralizes the concept of “becoming a teacher”, capable of delineating teaching skills manifested in and for intradisciplinary pedagogical practice. By means of this focus adjustment, it will also be possible the emergence of one more parameter, by which the formulation of this new form can suggest the reflection on the "internalizing the teacher", aiming, in this way, the probing of the participants regarding their own models for implementing teaching.

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Availability of research data: the dataset supporting the results of this study is published in this article.

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