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Contrasting the didactic skills and scientific literacy levels of Science teachers[+*Δ]

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Abstract

Possible correlations between scientific literacy skills and teaching abilities of teachers are examined through a qualitative-quantitative exploratory research approach. The study involved 18 (eighteen) elementary school teachers enrolled in a postgraduate strictosensu program who voluntarily participated in the Test of Scientific Literacy Skills (TOSLS) and created written proposals for didactic sequences. The research utilized the MAXQDA 2020 and JAMOVI 2.2.5 software for content analysis and descriptive statistics of the collected data. To analyze the proposed didactic sequences, a Didactic Skills Analysis Protocol (DSAP) was developed, with analysis categories inspired by contemporary constructivist educational ideas. Results from the categorization of indicators of teaching skills revealed that, on average, participants demonstrated half of the analyzed constructivist teaching skills and performed below the ideal level in the scientific literacy test. However, no significant correlations were found between components of the two constructs analyzed. While further research on teaching skills is necessary, the DSAP showed promising potential as an instrument for future research on the subject.

[+] Contrastando habilidades didáticas e níveis de letramento científico de professores de Ciências

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I. Introduction

With the aim of offering a possible contribution to the debate on the challenge of teacher training, this research explores the relationship between two important educational constructs. The first refers to so-called scientific literacy and its relationship with the ability to learn scientific concepts and the academic and professional competencies of people in general and teachers in particular (Gormally et. al, 2012). The second refers to the development of so-called didactic skills in teachers (Villani; Pacca, 1997; Carvalho; Gil-Perez, 1998).

A seminal theoretical discussion on so-called eminently constructivist didactic skills was developed in an essay by Villani and Pacca (1997). In it, in addition to detailing "teaching knowledge" they consider important, the authors, based on the results of their own studies and those of other researchers in the field, also argue that the so-called "disciplinary competencies" and "didactic skills" constitute a binomial in continuous interaction. And, although they did not mention the term, when discussing the importance of conceptual, historical, epistemological, and methodological mastery of scientific knowledge for teachers, Villani and Pacca (1997) list several elements of what is contemporarily understood as scientific literacy.

More recent studies, such as those by Santana and Franzolin (2018) and Gürler (2022), suggest that adequate scientific literacy among teachers is an essential condition for the effective implementation of eminently constructivist teaching strategies. However, it was not possible to find any study specifically dedicated to systematically and empirically investigating possible correlations between didactic skills and teachers' scientific literacy levels. This gap in the literature, in our view, justifies the need for research on such relationships, which are frequently assumed (Freitas; Villani, 2002; Ovigli; Bertucci, 2009, Leonard; Kalinowski; Andrews, 2014) but still little explored in the context of science teacher training.

In this study, to try to identify possible levels of scientific literacy and didactic skills in teachers, assessment instruments and techniques were used to enable discussion of the following research questions: Is there a correlation between scientific literacy skills and didactic skills? Is it possible to identify these skills and the possible correlations between them through the application of questionnaires and content analysis protocols? What are the most and least developed skills in a given group of teachers who teach science?

Thus, this exploratory qualitative-quantitative research uses content analysis and descriptive statistics to analyze the occurrence of different types of didactic and scientific literacy skills in a group of teachers, investigating the possibility of using content analysis protocols and standardized tests to investigate possible correlations between these two types of skills.

The hypothesis that there are correlations between didactic skills and scientific literacy skills is analyzed. In other words, the study attempts to assess whether scientifically literate teachers have a greater repertoire of constructivist didactic skills.

II. Theoretical framework

II.1 Teaching skills

Defining what a teaching (or didactic) skill is in a way that everyone agrees on is not a trivial matter. If we were to say that teaching skills are the strategies teachers use to enable children to learn, we would have to justify the exclusion of intimidation tactics and the use of punishments, used in schools in the not-too-distant past, for the purpose of making children learn certain things by force.

So, when seeking a definition of a teaching skill, it may be easier to exemplify and describe some of the characteristics of skills that can achieve some degree of consensus, though not universal agreement.

The first quality of a good teaching skill is obviously related to the ability to perform actions that facilitate student learning (Wragg, 1989). However, a second complementary quality of such a skill is that it is recognized as such by other people competent to judge this aspect, i.e., teachers, teacher trainers, inspectors, counselors, and the students themselves.

For it to be a recognized part of a teacher's professional competence, the skill must also be repeatable, perhaps not in exactly the same way, but as a fairly frequent occurrence, rather than occurring by chance. A chimpanzee might randomly paint an attractive colorful shape from time to time if given a brush and some paint, but a skilled artist will produce a skillfully conceived painting in a more planned and regular manner. Teachers who possess professional skills, therefore, must be able to manifest them consciously, and not by chance.

A problem found in the definition and use of the term teaching skills is that although in some contexts the term skill (and competence) has good connotations — seen as a rare quality, the result of years of practice, the mark of an expert — in other circumstances it is disparaged, considered mechanical, the sign of a crude technician and not an artist (Joyce; Weil; Calhoun, 2015).

This uncertainty about the proper position of the notion of skill when applied to teaching is partially explained by the varied nature of a teacher's work. On the one hand, properly connecting a multimedia projector or writing legibly on the blackboard requires very modest skills—which most people could learn with just a little practice. On the other hand, dealing with a restless teenager, or knowing how to explain an abstract concept to children of different ages and abilities—choosing the right language, appropriate examples and analogies, and providing them with different cues that indicate understanding or perplexity—requires years of practice, as well as considerable intelligence and discernment.

Many of the main skills emphasized in different conceptions of good teaching diverge significantly. The main teaching skills of constructivist conceptions, for example, as shown by Villani and Pacca (1997), are related to maintaining focus on student learning, carrying out activities that allow for the elicitation and discussion of prior concepts, and inducing cognitive conflicts, among others. Meanwhile, teaching models based on behavioral analysis recommend that teachers develop skills in defining clear objectives appropriate to the learners' abilities, providing comprehensible instructional guidance, continuously checking for learning, and giving good *feedback* at the right times, among other contingencies (Vargas, 2013).

There are still many other teaching models and consequently different sets of knowledge, competencies, and skills related to each of them (Joyce; Weil; Calhoun, 2015). However, this does not mean that some skills do not overlap. Certainly, the ability to offer clear instructions and give *feedback* to students are two skills that, let's say, cannot be missing regardless of the teaching model.

II.2. Didactic skills of constructivist teachers

As we have seen, the meaning and repertoire of didactic skills are intrinsically related to the theoretical framework that explicitly or implicitly underlies our teaching choices. Therefore, to define which skills we want to map, it is necessary to make explicit which pedagogical principles guide our choices.

As mentioned earlier, it was decided to base this investigation on a constructivist model of teaching and learning. Although an apparent constructivist consensus has had a great influence on many curriculum reforms in different countries (Novak, 1988; Bentley, 1998), there are currently different constructivist currents in the field of science teaching-learning research that have similarities and differences among them (Matthews, 2002).

That said, to better delineate our choices and justify any didactic principles and suggestions, we chose to base this work on the idea of constructivism defended by Gil-Pérez, Guisasola *et al.* (2005), since these authors analyzed contemporary criticisms of different types of constructivism and, from there, sought to clarify the theoretical bases of educational constructivism which, according to them, emerged from specific research in the area of science teaching-learning (*Science Education*). This approach aims for an educational process of (re)construction of knowledge through guided investigations that goes beyond the traditional transmission of knowledge, favoring debate on different Science, Technology, and Society (STS) aspects and encouraging citizen participation in decision-making.

According to Gil-Pérez, Guisasola *et al.* (2005, p. 111), the constructivist consensus in Science Education has its origin in many specific investigations related to different aspects of the science teaching-learning process, such as concept learning, problem-solving, experimental work, or attitudes towards science. According to them, these investigations have been developed with a view to improving the poor results of the reception/transmission learning paradigm, which has been seriously questioned by various educational research, as evidenced, for example, in studies on *misconceptions* and *alternative frameworks* (Leonard; Kalinowski; Andrews, 2014). Such investigations have contributed and continue to contribute to building a coherent body of knowledge that supports the need to involve students in the (re)construction of scientific knowledge, in order to make meaningful and lasting learning possible. This is the reason why Gil-Pérez, Guisasola *et al*. (2005) speak of knowledge construction and constructivism.

The proposal to organize student learning as a construction of knowledge, according to Gil-Pérez, Guisasola *et al*. (2005), corresponds to a guided investigation in areas perfectly known by the director of the investigation (the teacher), and where the partial and embryonic results obtained by the students can be reinforced, completed, or even questioned in light of those obtained by the "scientific community".

For a long time, constructivist-oriented authors, such as Shulman (1987), Villani and Pacca (1997), and Carvalho and Gil-Perez (1998), have debated different types of knowledge, wisdom, and competencies essential for science teachers, particularly teaching knowledge that can make science classes more stimulating and result in more meaningful learning for students. This discussion is the product of several years of research on science teaching-learning processes which, unfortunately, has found that many teachers take on their roles with extremely limited and ambiguous knowledge and with a vision and teaching practice incompatible with the advances of recent educational research (Freitas; Villani, 2002; Ovigli; Bertucci, 2009).

III. Methodology

III.1 Instruments

In order to identify, estimate, and analyze different didactic and scientific literacy skills of teachers, the following instruments were used: i) the Test of Scientific Literacy Skills (TOSLS) developed by Gormally *et al.* (2012): to assess the overall level and proficiency of different scientific literacy skills; ii) a protocol for the production and analysis of didactic sequences (PAHD): whose written textual content was used to qualitatively observe and categorize evidence of certain didactic skills essential for the planning and execution of constructivist-natured classes.

The operational definition of scientific literacy adopted in this research is the same as that adopted by the proponents of the TOSLS, i.e., the ability to use scientific knowledge to identify questions and draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it by human activity (Gormally *et al*., 2012)

The TOSLS is a questionnaire composed of 28 (twenty-eight) multiple-choice questions contextualized around real-world problems, for example, evaluating the reliability of a *website* containing scientific information or determining what constitutes evidence to support the effectiveness of a pharmaceutical product. The development process of the TOSLS sought to articulate the critical competence of scientific literacy by examining the validity of the instrument through interviews with students and experts in Biology teaching, pilot test-retests, subsequent examination of psychometric properties, and, finally, classroom tests of the final instrument in multiple and different Biology courses (Gormally *et al*., 2012).

In a study by Gomes and Almeida (2016), the TOSLS was translated from English, revised, and validated by Brazilian expert teachers in order to correct translation problems, eliminate possible inconsistencies, and attempt to contextualize the questions for the Brazilian reality.

The Protocol for the Collection and Analysis of Didactic Skills, which was designed to collect evidence of didactic skills through content analysis of lesson plans produced by teachers and/or by observing some of their classes. However, it is not difficult to imagine how hard it could be to find evidence of constructivist skills in lesson plans or even by observing classes *in loco* of teachers willing to collaborate with the research. Firstly, due to the time available to conduct *in loco* observations. Secondly, due to the difficulty in obtaining certain school documents (course plans). A third, and more important, aspect to consider is related to the fact that school infrastructure limitations, curriculum design, and content to be covered in a certain period of time, according to Scarinci and Pacca (2016), end up making even those well-prepared teachers willing to innovate decide to use, reluctantly, more conventional methods (expository classes), due to circumstances, working conditions, or even a lack of practice in teaching more constructivist-oriented classes.

Considering these difficulties, it was necessary to use a research instrument that would allow the elicitation of skills related to pedagogical principles present in teachers' thinking and, at the same time, was not limited to specific professional circumstances. To this end, we created a text production activity whose content was subjected to content analysis. Details of aspects of the implemented content analysis will be presented below.

Corpus: didactic sequences prepared by teachers who teach science in basic education, first-year students of a professional master's program in science education. The aforementioned handwritten texts were prepared during a course discipline. At the request of the course instructor, each participant voluntarily prepared a didactic sequence, according to the following guidelines:

> *Imagine yourself in an ideal school, with everything you could want to conduct your classes: a good salary, time for planning, adequate infrastructure, available teaching materials, etc. Describe the step-by-step process you would follow to carry out an innovative didactic sequence, in this ideal school, on a science topic of your choice, for students in classes you usually teach or would like to teach.*

The idea of this activity was to encourage teachers and let them feel free to express all their possible theoretical-methodological aspirations which, due to curricular, infrastructure, and time limitations, are often not put into practice in the schools where they work. With this, there are greater chances of observing the occurrence of descriptions of actions and concerns related to different didactic skills and inferring which skills might be present or not in the discourse of the investigated teachers.

Unit of registration: in this case, the texts produced by each teacher, i.e., the didactic sequences they prepared.

Unit of context: in the search to explore possible implicit patterns, information such as the teachers' undergraduate course, age, and time in the profession were considered as units of context.

Categories: *a priori* categories were created to aggregate semantic information units. That is, the constructivist theoretical framework (Villani; Pacca, 1997; Gil-Pérez; Guisasola *et al*., 2005) was used to create categories related to the skills of an ideal constructivist teacher (advocated by the theory) and to allow a categorical analysis capable of organizing themes expressed in certain excerpts (sentences and paragraphs) that are explicitly or implicitly related to the respective didactic skills expressed by the proposed categories. In addition to the *a priori* categories, to meet the criterion of exhaustiveness, some *a posteriori* categories were also created during the analysis to categorize excerpts that did not fit into any of the initially proposed categories and to try to express all relevant aspects existing in the data.

The 27 (twenty-seven) didactic skills that make up the PAHD are presented below, grouped into five macro sets (dimensions), the details of which are shown in tables 1.1, 1.2, 1.3, 1.4, and 1.5, respectively:

Table 1.1 – Analysis categories: constructivist didactic skills related to the Planning dimension.

1. Planning	
1.1. Articulate activities with long-term plans	Show evidence of connection with activities or objects of knowledge that may have been addressed in previous or subsequent classes and not simply treated in isolation.
1.2. Explore STS aspects	Encourage students to reflect on possible STS aspects that may be related to the subject in question: social implications, historical contexts, environmental consequences, and/or political aspects.
1.3. Define specific goals for each class or didactic sequence	Stipulate learning goals clearly, particularly aiming for skills and competencies related to conceptual, procedural, and attitudinal aspects typical of scientific knowledge.
1.4. Plan the development of classes consistent with student abilities and proposed goals	Take into account age, possible special needs, and/or prior learning probes when planning different educational activities.
1.5. Organize different consultation sources and references	Conduct a survey and prior organization of texts, books, websites, and/or videos that can be used as a source of consultation and reference before, during, or after the proposed activities.
1.6. Organize different didactic materials for the activities	Conduct a survey and prior organization of apparatus, games, laboratories, and/or visitation sites that will be used in carrying out the proposed activities.

1.7. Make use of didactic research and innovation	Coherently and effectively base the activities on one or more educational theoretical frameworks.
1.7.1. Demonstrate coherence between theoretical assumptions and didactic proposals[2]	The theoretical principles mentioned are being used coherently and effectively in the planning, execution, and evaluation of the proposed activities.
1.7.2. Mention pedagogical principles but not actually use them[3]	The theoretical principles mentioned in the plan do not seem to be used coherently and effectively in the planning, execution, and evaluation of the proposed activities.
1.10. Know and teach the use of Information and Communication Technologies (ICTs) to search for information and produce syntheses	Anticipate and demonstrate knowledge about the use of computers and/or smartphones to search for information and/or compose learning syntheses (concept maps, infographics, comparative charts, etc.).

Table 1.2 – Analysis categories: constructivist didactic skills related to the Prelude dimension.

2. **Prelude**	
2.1. Stimulate students' interest in the subject	Plan and carry out activities that stimulate students' curiosity and interest in the subjects to be addressed (storytelling, curious facts or phenomena, riddles, pre-assembly of apparatus, etc.) and awaken the novelty effect.
2.2. Develop and present stimulating and relevant problem questions	Start activities from problem-questions related to previously presented stories, facts, or phenomena, encouraging students to think about the subject and propose hypotheses and possible solutions.

Table 1.3 – Analysis categories: constructivist didactic skills related to the Elicitation and discussion of hypotheses dimension.

3. **Elicitation and discussion of hypotheses**	
3.1. Guide the elicitation of students' hypotheses	Help students formulate and state their hypotheses, encouraging them to express their points of view and helping to synthesize these points of view into assertive sentences in the format of hypotheses, so they can see in practice what this is about. Organize (on the board or in another type of note) the different hypotheses for the problem.

[2] Category created a *posteriori*, during the analysis of the lesson plans as a subcategory of the skill "Making use of didactic research and innovation".

[3] Category created a *posteriori*, during the analysis of the lesson plans as a subcategory of the skill "Making use of didactic research and innovation", but which cannot be considered a didactic skill. Only for the sake of exhaustiveness, it categorizes information present in the analyzed plans and serves as an object for discussion of the results.

3.2. Probe students' prior knowledge about the problem	When discussing the hypotheses, it will also be possible to check the students' prior knowledge on the subject, but this can also be done through questionnaires, texts, or other knowledge probing techniques.
3.3. Develop representations of students' prior knowledge for didactic use	Categorizing the different types of prior knowledge can be useful for organizing the level and sequence of activities, so it is important not only to probe them but also to categorize them systematically.
3.4. Imagine experimental *designs* to test hypotheses	The teacher can put up for discussion and help students imagine possible ways to test hypotheses, making them realize the importance of obtaining empirical evidence to more consistently support the hypotheses raised in the class.
3.5. Contrast prior knowledge with possible episodes from the History of Science	There are some teaching proposals that use historical controversies to stimulate students and show how the development of certain important scientific theories occurred, and how much some of the old accepted theories had similarities with possible prior knowledge presented by the students.

Table 1.4 – Analysis categories: constructivist didactic skills related to the Execution of activities dimension.

4. Execution of activities	
4.1. Provide instructions on what should be done.	Clearly and objectively state the instructions regarding what students should do in each of the tasks and/or stages of the class(es).
4.2. Stimulate and mediate debates and exchanges of ideas.	Have the ability to encourage shy students to speak up and properly manage the impetus of extroverted students to express their opinions, maintaining the mutual harmony and respect necessary on these occasions.
4.3. Make students give a favorable meaning to the didactic experience a priori.	As much as possible, keep students in activities that encourage them to think, propose opinions, and counter-argue in a logical and civilized manner, preventing them from acting as mere receivers and memorizers of information.
4.4. Continuously and on-the-fly adapt activities to the concrete responses of students.	Have the ability to adjust time, include or exclude previously scheduled activities, depending on the class's behavior. Since it is always possible that students may quickly solve problems that in the planning seemed to take more time to complete, or vice-versa.
4.5. Make learning goals flexible according to the progress and/or difficulties of the students	Based on the actual results and behaviors of the students during the activities, the teacher can make the initially proposed learning goals more or less flexible.
4.6. Encourage students to regulate their own learning	Giving examples of metacognitive strategies and opportunities for students to acquire and develop them (goal anticipation, self-assessment, selection and use of different problem-solving strategies, etc.)

4.7. Give students autonomy of choice	Provide opportunities for students to decide on certain aspects to be studied: formulation of questions and/or working hypotheses, assembly of experimental apparatus, research sources, forms of presenting results, etc.

Table 1.5 – Analysis categories: constructivist didactic skills related to the Assessment dimension.

5. **Assessment**	
5.1. Produce syntheses regarding student learning	Notes made by the teachers themselves to help them assess students' possible learning progress: annotations and/or logbooks, concept maps, synoptic charts, etc.
5.2. Propose and discuss assessment criteria consistent with the nature of the proposed activities and with the pre-established learning goals	Clearly explain to students the objectives of the proposed activities, the assessment instruments, and the criteria that will be used for each of them, making them aware of what they should effectively learn and thus prepare their tasks and self-assess better.
5.3. Provide *feedback*	Commenting on answers, clarifying doubts, guiding the execution of tasks, and explaining positive and negative points about students' behaviors, ideas, or productions is essential to help them acquire and practice the targeted skills and achieve the proposed objectives.
5.4. Encourage and guide the production of syntheses of what was learned (diagrams, memoirs, concept maps, infographics, etc.)	Using this type of graphical representation generally helps students gain a global and integrated understanding of the subject, in addition to helping them acquire and practice metacognitive strategies.

III.2 Research participants and data collection

Data were collected from a class of newly admitted students in a *stricto sensu* postgraduate course (master's degree) in science and mathematics education at a public university, during a course discipline, where the main author of the research and the course instructor explained the objectives, the type of data to be collected, and requested collaboration from those interested in participating. Eighteen (18) of the twenty-two (22) students in the class voluntarily agreed to participate in the research, signed a free and informed consent form, and prepared the requested didactic sequences during a class. In order to preserve their identities, a code was assigned to each participant, composed of their respective undergraduate degree course (Biology (BIO), Physics (FIS), Chemistry (QUI), Pedagogy (PED), Integrated Degree (INT)), a serial number (01, 02, 03...), and the teaching level at which they worked as a teacher (Early Years (AI), Final Years (AF), High School (EM)).

The data were collected in two sessions, both held in the final 60 minutes of the respective discipline's classes. In the first session, the objectives and intentions of the research and the tasks that would be requested of the participants were presented, leaving them free to participate or not. Then, the first request was to prepare the didactic sequence, the object of analysis for the PAHD. On that occasion, the participants had 60 minutes to individually prepare the proposal in writing on a sheet of lined paper provided to each of them. The instruction for the task of preparing the didactic sequence was written on the board. A week later, the participants were instructed to use the computers in the course's computer lab to answer the 28 questions of the TOSLS, available *online* on the *Google Forms* platform, having until the end of the class (60 minutes) to finish the test.

III.3 Data analysis

The qualitative data, after being duly transcribed, through content analysis (Bardin, 2004) and with the help of MAXQDA 2020 software, were tabulated into categories based on the literature on constructivist teaching skills (*a priori*) or on any categories that emerged during the analysis of said data (*a posteriori*). After undergoing this categorization, in addition to providing elements for qualitative descriptions of the occurrence or non-occurrence of certain teaching skills, it was also possible to quantify certain occurrences and use them as indices to be treated with quantitative analysis tools.

Jamovi software (version 2.2.5) was used to process quantitative data. First, descriptive statistics of frequencies, means, and variance were performed to analyze the occurrence and cross-referencing of different information regarding the data (total and partial scores of the TOSLS), to make it possible to ascertain any existing relationships between research variables expressed in simple frequency and cross-tabulation tables. A correlation matrix was also produced to assess the existence of correlated variables between the total and partial scores of the TOSLS and PAHD.

An attempt was made to use what Creswell and Clark (2015) call mixed methods research, that is, to analyze the set of collected information seeking to make qualitative inferences from quantitative data (and vice-versa).

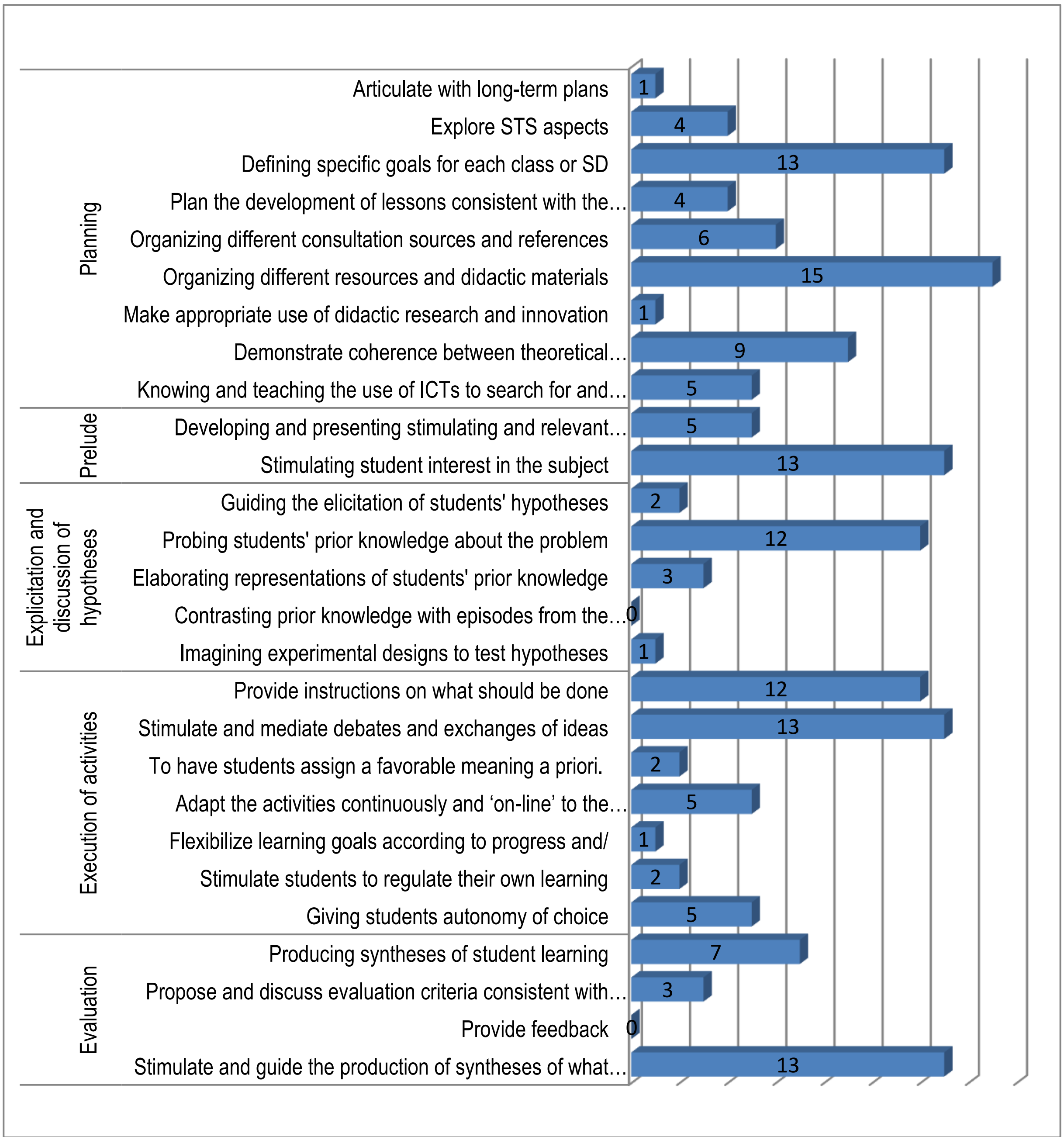
IV. Results and discussion

IV.1. Participant profile

The majority of the 18 (eighteen) teachers who participated in the survey are female (14; 77.7%) and are over 30 years old (12; 66.6%). There are teachers who work at different levels of Basic Education: Early childhood education (1; 5.5%); Early years of elementary school (8; 44.4%), Final years of elementary school (4; 22.2%), and High school (5; 27.7%); and from different undergraduate degree courses: Pedagogy (7; 38.8%), Biology (6; 33.3%), Integrated Degree (2; 11.1%), Chemistry (2; 11.1%), and Physics (1; 5.5%).

IV.2 Analysis of the dimensions and categories proposed in the PAHD

Graph 1 shows the number of participants who showed evidence of the respective 27 proposed didactic skills. In it, it is possible to observe that only 7 (seven) skills had a high frequency of evidence, detected in the lesson plans through content analysis. The complete tables with the excerpts referring to each skill identified in the respective teachers' lesson plans, as well as the details of the statistical analyses performed, can be consulted in Gomes (2022).



Graph 1 – Frequency of occurrence of the different didactic skills of the PAHD.

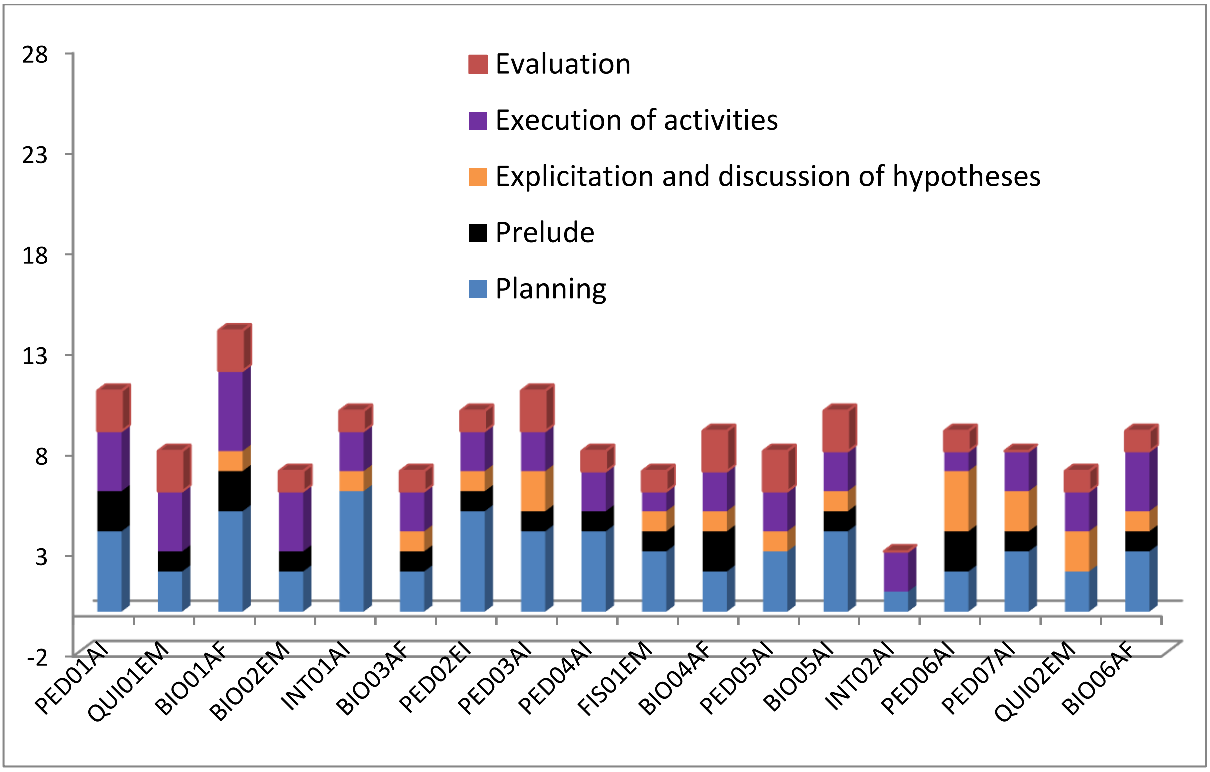
In the 'Planning' dimension, it is possible to observe in Graph 1 that the skills of Organizing different didactic materials for the activities (15 occurrences) and Defining specific goals for each class or didactic sequence (13 occurrences) stand out, both presented by more than half of the investigated participants. It can be inferred that the high incidence of both is a reflection of the systematic planning tradition initiated in the 1960s by works such as those of Tyler (1950) and Mager (1962). Half of the participants also showed evidence of coherence between theoretical assumptions and didactic proposals. Something very important for conducting coherent and didactically grounded classes. On the other hand, the other 6 (six) skills related to the ‘Planning’ dimension had a low incidence among the participants. Mainly the skills of Articulating activities with long-term plans and Making use of didactic research and innovation, both essential for the preparation and execution of classes, whether they are constructivist in nature or not.

The two skills belonging to the dimension named 'Prelude' in this research also showed a significant difference in occurrences. While the skill of *Stimulating students' interest in the subject* appeared quite frequently in the participants' didactic sequence proposals, the same did not happen with the skill of *Developing and presenting stimulating and relevant problem questions* (see Graph 1). The latter, a key skill for putting eminently constructivist classes into practice, evidence of which was found in the lesson plans of only 5 (five) participants.

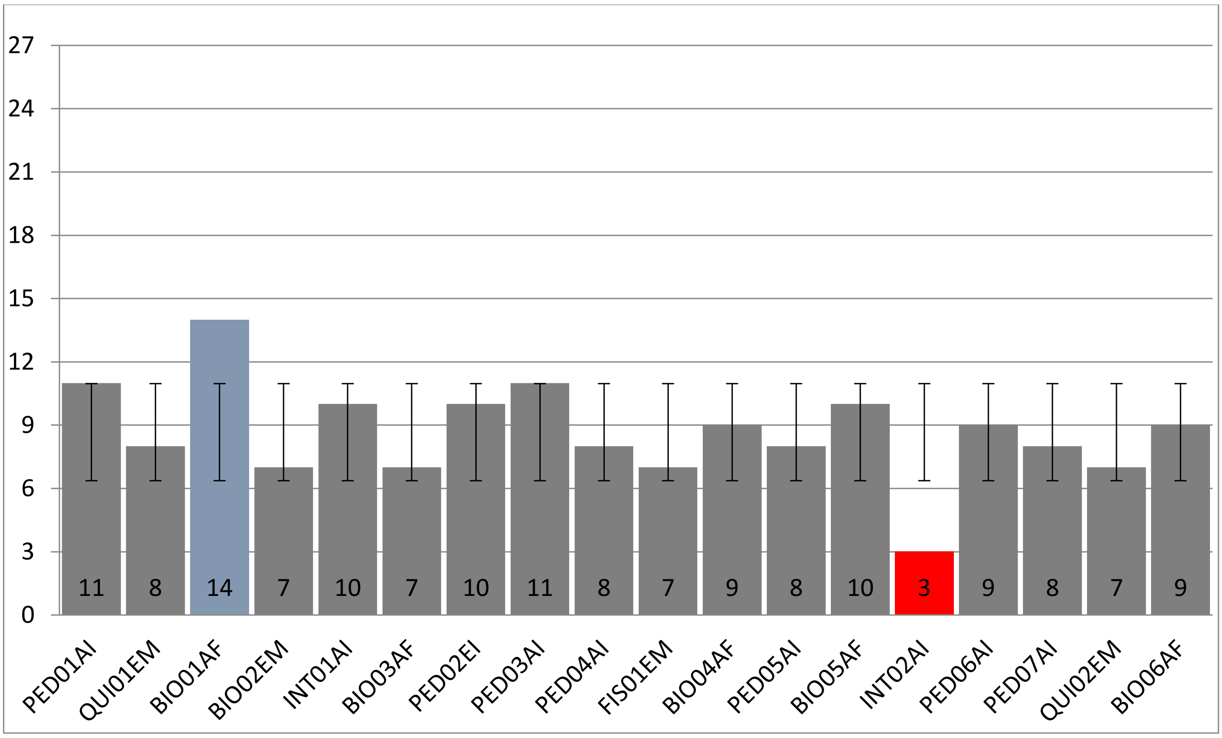
Of the five different skills categorized in the 'Elicitation and discussion of hypotheses' dimension, only the skill of *Probing students' prior knowledge about the problem* showed good frequency among the participants. The others seem to have been widely neglected in the participants' didactic sequence proposals, especially the skill of *Contrasting prior knowledge with possible episodes from the History of Science*, evidence of which was not found in any of the participants' proposals (see Graph 1).

Graph 2 presents the distribution of the occurrence of evidence for the different skill dimensions among the participants. In it, it is possible to see that, with the exception of one participant (BIO01AF), the others presented less than half of the 27 proposed skills. In Graph 2, it is also possible to note that evidence of skills that appeared most among the participants refers to the 'Planning', 'Execution of activities', and 'Assessment' dimensions. Skills related to the 'Elicitation and discussion of hypotheses' and 'Prelude' dimensions did not even appear in the proposals of some participants.

In terms of the sum of different didactic skills, Graph 3 shows that, with the exception of two teachers (BIO01AF, 14 and INT02AI, 3), the sums of the occurrences of teachers' didactic skills remained close to the average of 8.5 occurrences (within the limits of the standard deviation). That is, approximately 1/3 of the 27 targeted didactic skills. We can also observe that there are only two outliers: BIO01AF, with 14 skills recorded, i.e., well above the average of 8.5 skills, and INT02AI, with only 3 skills recorded, i.e., well below the participants' average.



Graph 2 – Frequencies of the different sets of didactic skills per teacher.



Graph 3 – Dispersion of the frequencies of the sum of teachers' didactic skills (maximum value = 27).

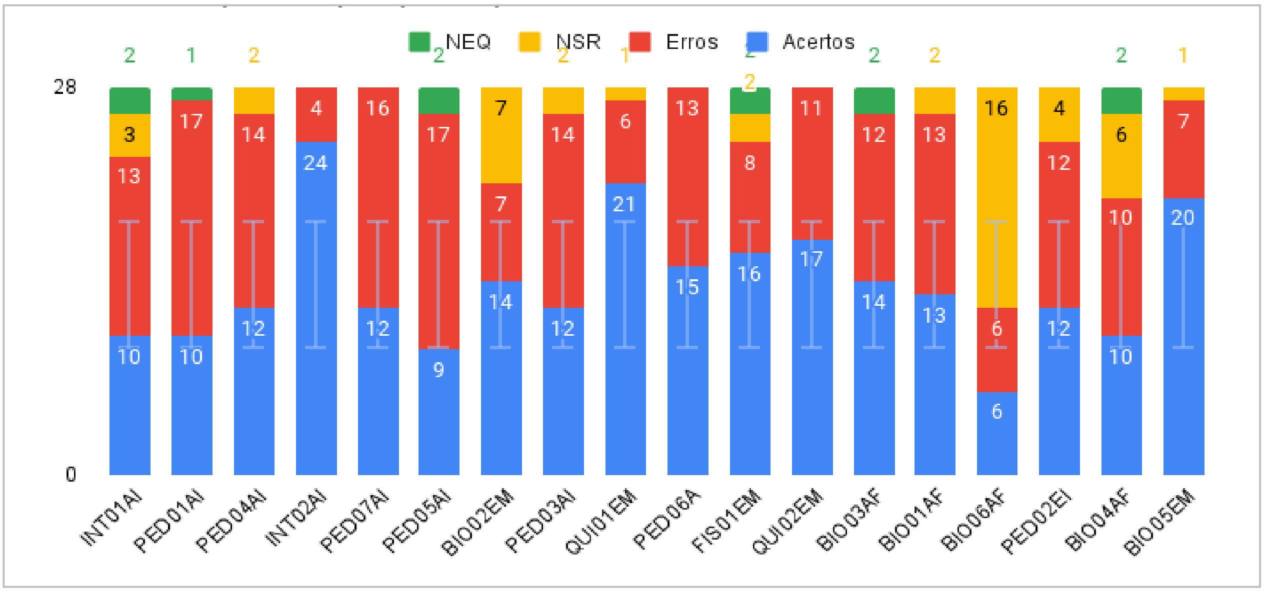
TOSLS results and skill correlation analysis

Table 1 presents the descriptive statistics of the test. In it, we can see that, of the 28 TOSLS questions, the participants' average number of correct answers was 13. The highest number of correct answers was obtained by teacher INT02AI (24 correct answers) and the lowest by teacher BIO06AF (6 correct answers). Both cases were considered outliers, as they exceed the limit of the deviation of 4.47 points above or below the mean, which, in this case, includes 77.7% of the participants, i.e., 77.7% of the participants obtained 12 ±4.47 correct answers. A number well below the 75% of correct answers (21 or more questions) considered by the instrument's developers as an indicator of an adequate level of scientific literacy (GORMALLY *et al*., 2012).

Table 1 – Descriptive statistics of TOSLS correct answers.

N	18	Minimum	6
Mean correct answers	13,0	Maximum	24
Standard Deviation	4,47	Median	12,0
Sum	234	Mode	9,0

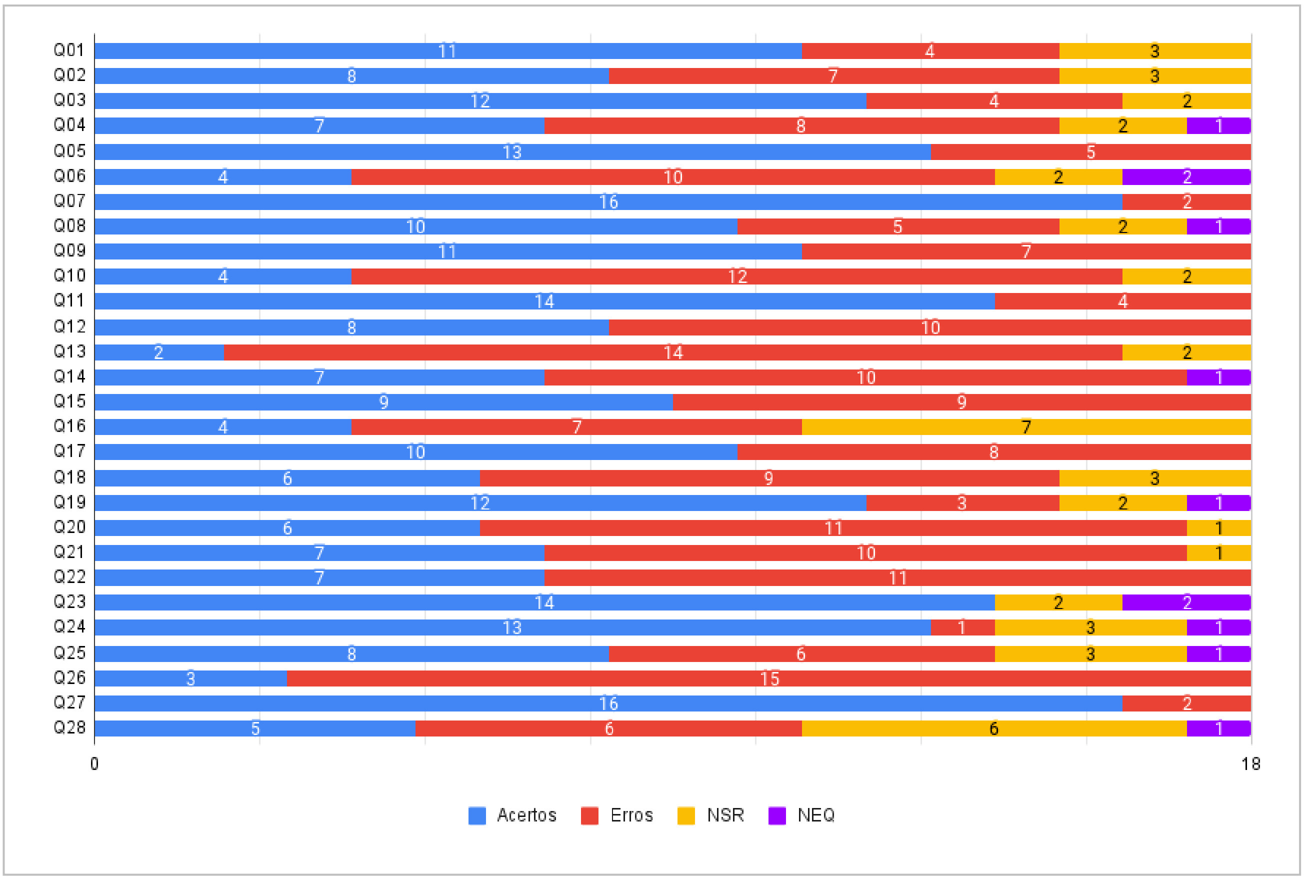
Graph 4 presents the results of each participant by the type of alternative selected for each question. In it, it is possible to observe that most cases fall within the standard deviation and four are outliers (INT02AI, 24; QUIM02EM, 21; BIO06AF, 6 and BIO05EM, 20). In the aforementioned graph, it is also possible to observe the frequency of errors and the choice of the alternatives *I did not understand the question* (NEQ) and *I do not know the answer* (NSR).



Graph 4 – TOSLS: Responses per participant.

Graph 5 presents the profile of responses per question. In it, it is possible to observe that questions 13 and 26 were the ones for which participants most often selected wrong alternatives; only 2 and 3 participants, respectively, got the correct answer. Question 13 is related to the specific skill of *recognizing possible interferences and biases in research* [H4] and question 26 to the specific skill of *Evaluate the validity of sources* [H2]. The aforementioned graph also shows that questions 7 and 27 had the highest number of correct answers among the participants. The first is part of the set of questions related to the specific skill of *Read and interpret graphical representations of data* [H6] and the second with the skill of *Evaluate the use and misuse of scientific information* [H3].

In order to have a more detailed view of the participants' performance in each of the specific skills of the TOSLS, a graph was plotted showing the percentage of correct answers in the set of questions for each specific skill (Graph 6).

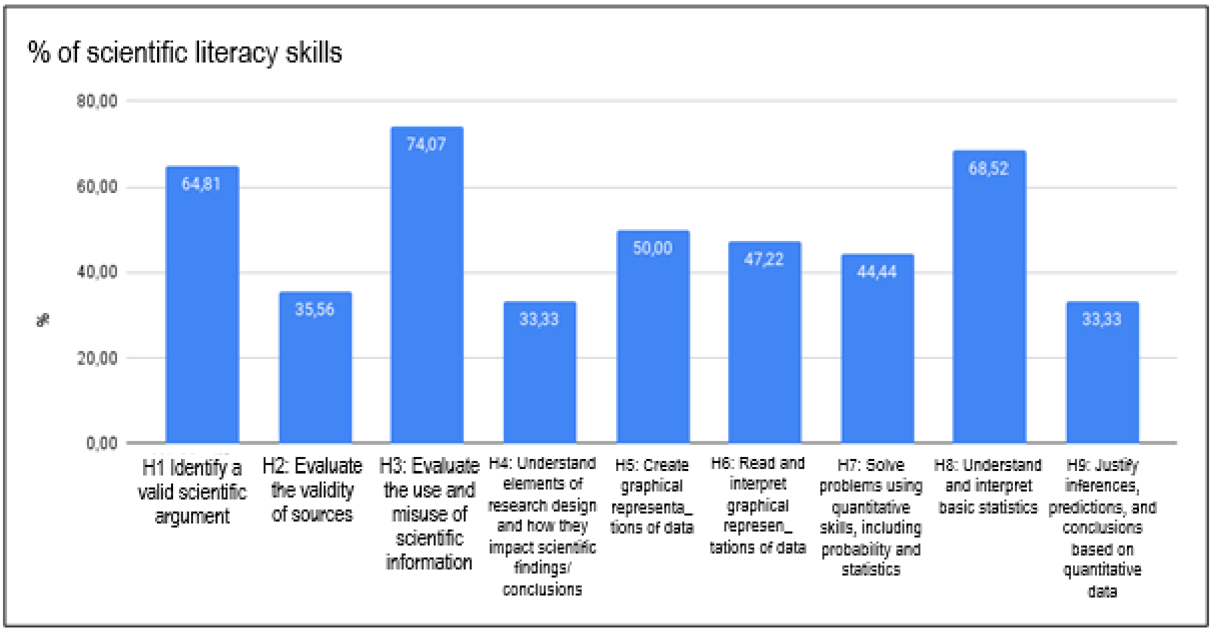


Graph 5 – TOSLS: responses per question.

For example, the skill of identifying a valid scientific argument is measured by the sum of correct answers to questions 01, 08, and 11. With this, it is possible to observe that the participants performed best in the skills of *Evaluate the use and misuse of scientific information* [H3] (74.07%), *Understand and interpret basic statistics* [H8] (68.52%), and *Identify a valid scientific argument* [H1] (64.81), a medium performance in the skills of Interpreting histograms

[H5] (50.%), *Read and interpret graphical representations of data* [H6] (47.22%), and *Solve problems using quantitative skills, including probability and statistics* [H7] (44.44%), and a weak performance in the skills of *Evaluate the validity of sources* [H2] (35.56%), Recognizing possible interferences and biases [H4] (33.33%), and *Justify inferences, predictions, and conclusions based on quantitative data* [H9] (33.33%). These performance levels per skill are quite close to the results obtained by another group of teachers who also answered the TOSLS (Gomes; Almeida, 2016).

To contrast and analyze possible correlations between the scientific literacy skill scores and didactic skill scores, using functions of the Jamovi software (version 2.2.5), descriptive statistics and a correlation matrix of different quantitative variables obtained through data tabulation were calculated, which will be discussed below.



Graph 6 – TOSLS: Results of scientific literacy skill subscores.

Table 2 – TOSLS and PAHD means by teaching level subgroups.

	Teaching level	N	Mean	DP	Min.	Max.
Total_Didactic_Skills	Early years – AI	8	8.50	2.56	3	11
	High School – EM	5	7.80	1.30	7	10
	Final years – Fundamental Education – AF	4	9.75	2.99	7	14
	Early childhood education – EI	1	10	–	10	10
Total_SL	Early years – AI	8	13.00	4.81	9	24
	High School – EM	5	17.60	2.88	14	21
	Final years – Fundamental Education – AF	4	10.75	3.59	6	14
	Early childhood education – EI	1	12	–	12	12

Table 2 contains the descriptive statistics, separating the participants into subgroups related to the respective teaching levels at which they work as teachers. In it, it is possible to observe that the participants who teach in the final years of elementary school, disregarding the unique case of the teacher who works in early childhood education, obtained a slightly higher average didactic skills score than the other groups. On the other hand, the subgroup of participants who teach in the Final Years of ES obtained the lowest average total TOSLS score, with the participants who teach in High School showing, on average, the best performance on the said test.

Table 3 shows that both the subgroup of graduates in Pedagogy and the graduates in Biology obtained, on average, a slightly higher total PAHD score than the other subgroups. On the other hand, the highest TOSLS scores were obtained by the participants who graduated in Chemistry. It is important to note that the average of 17 points on the TOSLS obtained by the subgroup of graduates in the Integrated Licentiate was caused by the outlier case and the fact that the said subgroup has only two members; this discrepancy is evidenced by the standard deviation of 9.89, well above the other subgroups.

Table 3 - TOSLS and PAHD means by undergraduate degree course subgroups.

	Undergraduate degree	**N**	**Mean**	**DP**	**Min.**	**Max.**
Total_Didactic_ Skills	Education (Pedagogy) – PED	7	.00	1.38	8	11
	Chemistry Licentiate – QUI	2	7.50	0.70	7	8
	Biology Licentiate – BIO	6	9.00	2.58	7	14
	Integrated Licentiate – INT	2	6.50	4.95	3	10
	Physics Licentiate – FIS	1	7	–	7	7
Education (Pedagogy)	Education (Pedagogy) – PED	7	12.00	1.89	9	15
	Chemistry Licentiate – QUI	2	19.00	2.83	17	21
	Biology Licentiate – BIO	6	13.50	4.66	6	20
	Integrated Licentiate – INT	2	17.00	9.89	10	24
	Physics Licentiate - FIS	1	16	–	16	16

The results expressed in tables 2 and 3 show that when the means of the total TOSLS and PAHD scores of the different subgroups are calculated, there is an irregular variation between them. Unfortunately, due to the small sample size, the existence of subgroups with only one individual, and significant differences in the number of individuals in each subgroup, it was not possible to perform an analysis of variance, which would allow for the calculation of statistical parameters and the quantitative estimation of possible similarities or differences in the variation of the means across the different subgroups.

Finally, to statistically evaluate possible correlations between different quantitative variables obtained through the application of the PAHD and TOSLS to the participants of this research, a correlation matrix was used, also generated with the help of the Jamovi software (version 2.2.5), which contrasted the results of the total scores of the PAHD (Total_HD) and the TOSLS (Total_LC), in addition to 14 subscores of the instruments (9 from the TOSLS and 5 from the PAHD).

Because it was a small sample, two different correlation coefficients were used: Kendall's Tau B and Spearman'srho. The first is more recommended for small, non-parametric samples. However, the data passed the Shapiro-Wilk normality test (Shapiro-Wilk: 0.949 with p: 0.403 for the Total_LC scores and Shapiro-Wilk: 0.934 with p: 0.429 for the Total_HD scores) which allowed, despite the small sample size, the use of the Spearman'srho test (Sassi, 2020). Therefore, for the purpose of contrast and complementation of coefficients, it was deemed appropriate to use both. This would make it possible to observe the differences and any convergences or discrepancies between them.

That said, when contrasting the total scores of the PAHD and the TOSLS, although the significance level (0.056) related to the Spearman'srho coefficient approached the statistically significant value ($p > 0.05$), it is not possible to state that the obtained Spearman'srho coefficient (– 0.458) expresses a negative correlation between the said scores within a statistically acceptable margin of error. This objection is corroborated by the Kendall's Tau B coefficient (– 0.332) and its significance level (0.076), also above a statistically acceptable value ($p > 0.05$). Probably, because the sample was small, these results were induced by the outlier scores of teachers INT02AI and QUIM02EM, who obtained high scores on the TOSLS (24 and 21, respectively) and low scores on the PAHD (3 and 8, respectively).

Although the total scores of PAHD and TOSLS were not statistically correlated, interestingly the PAHD Planning skills subscore showed a moderate positive correlation with the skill of *Justify inferences, predictions, and conclusions based on quantitative data* [H9] of the TOSLS (Spearman'srho: 0.628 with p: 0.005; Kendall's Tau B: 0.566 with p: 0.005). This, in a way, corroborates research such as that of Santana and Franzolin (2018) which demonstrated that difficulties in planning investigative activities are closely related to the teachers' conceptual and procedural mastery of the content to be discussed in class.

It is worth mentioning that, although the set of didactic skills organized in the Planning dimension includes more general and routine skills (such as *Defining specific goals for each class or didactic sequence* and *Organizing different didactic materials for the activities*), most of the skills listed in this dimension are peculiar to the planning of investigative-type activities (for example, *Exploring STS aspects*, *Planning the development of classes consistent with student abilities and proposed goals*, *Making use of didactic research and innovation*, and *Knowing and teaching the use of ICTs to search for information and produce syntheses*), precisely the skills detected most frequently among teachers who obtained better performance on the TOSLS.

The other statistically significant correlations indicated in the correlation matrix were found between the total score and subscores of the PAHD itself which, like the correlations between subscores of the TOSLS, were not the object of analysis in this study. It is important to clarify that correlations between subscores could be used to assess the internal consistency of the instruments; however, for this, a larger sample with a more homogeneous distribution among any subgroups would be necessary, which, as already mentioned, are not characteristics of the group of participants in question.

V. Final considerations

In summary, it is possible to state that the analysis of the results of the categorization of evidence of teaching skills showed that the research participants presented, on average, only half of the constructivist-natured teaching skills proposed in the PAHD. Furthermore, they obtained an average of correct answers on the TOSLS questions that was below the ideal.

With the exception of the skill of *Probing students' prior knowledge about the problem*, it is plausible to infer that the most frequently detected skills are reflections of a certain heritage from technicist teaching models, widely disseminated since the 1960s. For example, currently, although the elaboration of objectives, choice of didactic materials, and assessment goals no longer follow the rigid standards recommended by Tyler (1950) and Mager (1962), they continue to be present in curriculum guidelines, course and discipline syllabi, didactic sequences, and other types of educational plans. Therefore, they are part of the writing standard that has been disseminated among current and future teachers, whether during initial and continuing education courses or in magazines, books, and websites that publish ideas for conducting classes. In contrast, the higher incidence of excerpts related to the concern of *Probing students' prior knowledge about the problem* can probably be a reflection of the current influence of ideas from various constructivist educators who ended up becoming references for the development of many didactic materials, curricula, and science teacher training courses since the 1990s.

On the other hand, the skills with the lowest incidence rate among the participants (2 or fewer occurrences) were *Articulating activities with long-term plans*, *Making use of didactic research and innovation* (Planning); *Guiding the elicitation of students' hypotheses*, *Contrasting prior knowledge with possible episodes from the History of Science*, *Imagining experimental designs to test hypotheses* (Elicitation and discussion of hypotheses); *Making students give a favorable meaning to the didactic experience a priori*, *Making learning goals flexible according to the progress and/or difficulties of the students* (Execution of activities); *Encouraging students to regulate their own learning*, *Providing feedback* (Assessment). All are more closely related to a more consistent constructivist teaching model, defended by Gil-Pérez; Guisasola *et al*., 2005, where the focus of learning is on the student who engages in arguments based on data and knowledge obtained through active search and self-regulation of learning.

The results suggest that, if there is an interest in truly implementing constructivist-natured curriculum guidelines and teaching-learning-assessment strategies in schools, it is necessary to enhance teacher training programs with objectives, themes, and teaching strategies focused on skills that showed low incidence in this study. Since, as previously discussed, all are essential for the planning and execution of constructivist-natured classes and important for the professional development of science teachers.

As for the results of the statistical tests applied to the quantitative data regarding the scoring of total scores and skill subscores, it was demonstrated that there is no significant correlation between the total scores of the PAHD and TOSLS. However, it is not possible to rule out the possibility of observing statistically significant correlations between didactic skills and scientific literacy in sufficiently larger and more diverse samples.

On the other hand, although the protocol for the analysis of didactic skills (PAHD), developed and applied in this study, proved to be appropriate for the researched circumstances, due to the nature of certain qualitative analyses used, the interpretations and conclusions presented are naturally subject to the problems of reliability and trustworthiness that any analysis of this nature faces.

In any case, the data and results presented demonstrate that the proposed protocol for the analysis of didactic skills offers potential benefits for researchers interested in deepening studies on constructivist-natured teaching skills. The PAHD, in particular, has great potential both for future research on the skills of science teachers and for guiding eventual reformulations in the training programs for these professionals.

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