How do you argue in physics class? A systematic review from 2018-2023

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ABSTRACT

This article examines the evolution of the teaching-learning process in science, focusing on argumentation as an essential component, especially in the field of physics. The growing interest in dialogic argumentation in the scientific community stands out, recognized for its ability to enhance learning and contribute to the social construction of knowledge. The relationship between argumentation skills, critical thinking and problem solving in science teaching is emphasized, using Toulmin's model as a framework to analyze the structure of an argument. The concept of Sense Making is explored in the context of argumentation in physics teaching. The methodology includes a systematic review of the literature of the last five years using the PRISMA methodology, revealing consistency in the publication of articles on argumentation in physics teaching. The role of teacher educators as guides in constructivist activities is addressed, while preservice teachers play a central role in the argumentative process.

Keywords: Teaching of physics, Argumentation, Creation of meaning.

INTRODUCTION

When thinking about education, one might ask: how much and to what extent has learning changed in recent times? This article does not attempt to answer this question in its entirety, as it would require a broader review and, on more topics, than it intends to address here. However, these questions have another behind them: has the teaching-learning process changed in the last century? Particularly in science or physics.
Thus, research on argumentation has increased in the last 15 years in the scientific community due to the potential of this skill to increase learning. Within the process of arguing, the negotiation of meanings and the construction of social knowledge is of special interest [1]. That is, arguing positively promotes learning and has become a process of particular relevance for science teaching.
This is because, as said previously, argumentation is related to communicating an idea [2], so the importance of dialogic argumentation in science teaching has been widely accepted as an essential social activity for students to participate in the reasoning of their peers [3], which would allow them to participate in a collective construction of scientific knowledge.
Along the same lines, [4] proposes that, in science teaching, the ability to argue is an essential component of critical thinking and problem-solving skills. The same authors point out that, in particular, the ability to construct, justify and defend an argument based on evidence and reasoning is key to evaluating scientific hypotheses. Defending an argument, being able to think critically or make someone understand what is meant is of special importance for the teaching of science and in particular physics, since this process allows, through dialogue with others, to use scientific language, which implies understanding the argument being defended.
The latter has become relevant for science teaching, as [3] points out, where despite years of efforts to promote argumentation in science classrooms, argumentation is rarely produced or developed productively by students, who remain in a passive role. In fact, the classroom is still full of monologues from the teachers.
With everything stated above, the question that guides this study is:
What does the literature in the last five years report about the way arguments are developing in the science classroom, particularly in physics?

THEORETICAL FRAMEWORK

Argumentation

Described as the process of systematic reasoning in support of an idea or theory or as "the use of evidence to persuade an audience" [5], argumentation is at the heart of science and scientific research, so it deserves a central place in science teaching in general and in scientific research in particular [6].

In this sense, it is thought that evidence-based argumentation allows us to reflect on the quality of arguments, clarify or criticize ideas clearly, propose solutions and alternatives to complex problems, and convince others to accept valid

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conclusions [4]. In that same sense, it can be said that the ability to argue becomes one of the main objectives of learning science because it becomes a tool to find scientific explanations about natural phenomena, and use them to solve problems [2].

In this sense, it has been found that argumentation - the process of generating an argument - promotes students' understanding of how scientific knowledge is constructed, in addition to promoting content knowledge in science, and is a fundamental epistemic practice in the science learning [7].

Now, despite how important the argumentative process is said to be, it is considered that the argument has had problems developing in the classroom, either by teachers or when students are asked to argue their positions. Despite this, when someone is asked to argue this claim, it usually implies that the most used framework for analyzing the structure of an argument is the Toulmin Argumentation Pattern [8].

Toulmin model

Below is the scheme proposed by [9], for the construction of an argument.

Toulmin's argumentative model illustrates the structure of an argument that connects a claim (statement), the data that supports the claim, the warrant that provides a relationship between the data and the claim, the support that reinforces the order, and finally the refutation of a statement [9] Specifically, Toulmin defines a claim as a statement that must be accepted, data is evidence that supports the claim, support is a basic theory that generates confidence in the claims, and refutation is a condition of exclusion or refutation of an argument [2].

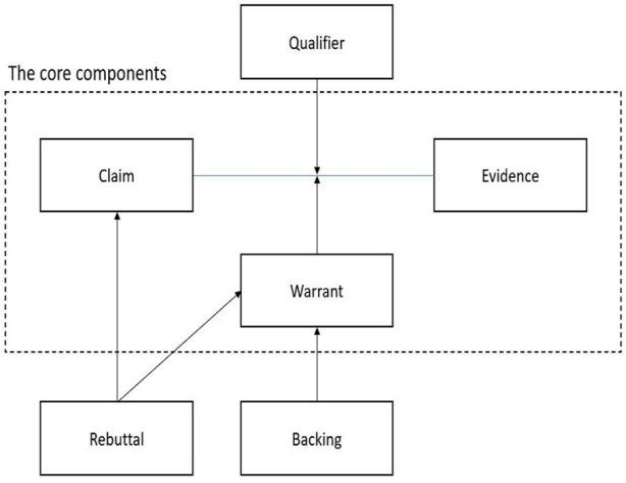

Figure 1. Toulmin's argumentative

Sense Making

The Sense Making is a dynamic process that allows students to resolve missing knowledge through co-construction of knowledge based on prior knowledge [10]. For example, students are able to make sense of mathematics when they use concrete mathematics from their everyday experiences and connect it to abstract mathematics. Likewise, it is understood that the Sense Making has the goal of "discovering something" [5]. This process is usually motivated by the purpose of discovering the underlying mechanism of an observed phenomenon. Some authors [12]; [10], [11]; [13] propose that Sense Makingse is understood as “a process in which a group works to develop a mutually negotiated understanding of a phenomenon” [5].

If we think about argumentation in the physics classroom, it is necessary, for the teaching of physics itself, to understand that Sense Making in said classroom facilitates the expression of ideas by students, which together could allow better learning. This includes contributing to the conceptual understanding of physics and not remaining only in the spaces of mathematical exercise [14]. In doing so, they coordinate multiple representations and use quantitative reasoning to obtain qualitative knowledge and vice versa. This last idea is related to the mathematization process that will be reviewed in the next section.

METHODOLOGY

To understand the current state of research describing the way arguments are being developed in university physics classes, a systematic review of the literature has been carried out.

To carry out this review, we worked with the PRISMA methodology, ending the last bibliographic search on October 17, 2023 in the following databases: Web of Science (WoS) and Scopus. In both databases the review was carried out in English. These databases have high-quality indexing standards and a great international reputation. In addition, they contain many studies in the field of educational [15]. Table 1 is shown below, presenting the keywords and booleans used to complete the search.

Table 1. Keywords from the systematic review in WoS and Scoupus

Review Keywords	
Wos	(Argumentation) OR ("scientific argumentation") AND (physics) OR ("teacher trainer") AND (physics) AND (mathematics*)
Scopus	(Argumentation) OR ("scientific argumentation") AND (professor) OR (teaching) AND (science) OR (physics) AND (mathematics*)

The present study seeks to identify how arguments are argued in the university physics classroom, so the main focus of attention was directed to those articles that referred to initial teacher training. Table 2 explains the inclusion and exclusion criteria that were taken into account for the selection of the articles.

Table 2. Inclusion and exclusion criteria

Inclusion	Exclusion
The articles focused on what was happening in teacher training	The articles were scientific
The article was about education	The object of study of the articles was the school Students
Only articles in English were included.	The articles focused solely on mathematics teaching
When reviewing the title, summary or methodology, reference was made to the teaching of physics and/or mathematics	These were other bibliographic reviews
When reviewing the title, summary or methodology, reference was made to teachers in training and/or teacher trainers	

It is relevant to note that the review was carried out only with articles published in the last 5 years. Below is the flow chart that allowed us to reach the reviewed articles.

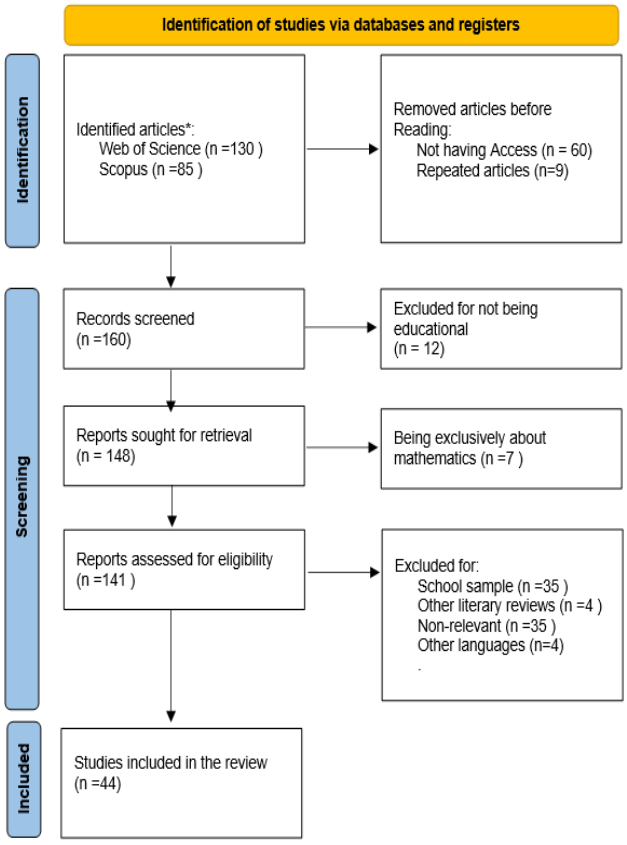

Figure 2. Flowchart for the selection of reviewed articles

To carry out this systematic review, we began with a search in two databases, Web of Science and Scopus. These databases were selected because they publish articles with greater impact and better indexing. Initially, 130 articles were found in WoS and 85 in Scopus. These results emerged after adding several keywords such as "scientific argumentation," physics, teacher, teaching, mathematics*, and "teacher educator." It is important to note that the search included articles that referred to Mathematical Argumentation in search of the mathematization process, despite the fact that this was not declared and the skills of formulating mathematical arguments that were assimilated to the aforementioned process could be found. The Boolean operators AND and OR were used for the search. Then, the search was limited to the last 5 years (2018 to 2023) to have a more recent approach to what was reported in the literature. With the 210 articles selected, the titles, abstracts and methodologies were read for references to the training of physics or mathematics teachers, either with pre-service teachers or with the teacher educator. In this process, those that were only scientific or only related to mathematics were eliminated; in addition, those that had the school population as a study subject were not selected either. For this research, the other bibliographic reviews were not relevant, so articles that did this type of work were not considered either. Finally, those articles that were not in English and that did not directly talk about the argumentation were excluded. After this process, 44 articles were selected to be analyzed.

ANALYSIS

The data analysis was carried out with the 44 selected articles, which were read, placing special emphasis on how argumentative interactions were declared in the initial training of teachers or by the trainers of future physics teachers. This is for the purpose of answering the question that guides this literary review. What does the literature report in the last five years about how the initial training of physics teachers is argued?

The research question was answered from two secondary questions. These questions would be:

1) How do physics teacher educators use argumentation in the teaching process of their discipline? AND

2) How are physics students asked to argue their positions on the discipline?

Then, a qualitative approach was adopted to analyze the data found. To do this, the articles were read with special emphasis on the methodologies and results, in order to identify what role both teachers and students (future teachers) played in the argumentative process. Data were taken from these spaces in the documents and patterns were identified or inferred in the analyzed documents.

The following section shows the results obtained after focused reading of the selected articles.

RESULTS

44 articles were analyzed, of which their distribution in recent years is seen in the following table:

Table 3. Number of articles found per year

Year of publication	Quantity of Articles found
2018	3
2019	7
2020	12
2021	6
2022	4
2023	7

Table 4. Number of articles found by country

Country	Number of articles on Argumentation analyzed
Does not indicate	4
Turkey	5
USA	11
Finland	2
Ireland	1
Ethiopia	1
South Africa	2
Portugal	1
Spain	2
Brazil	1
Greece	1
Indonesia	8
Holland	2
Sweden	2
Austria	1

A first finding is that during the year 2020 was when the argumentation in the university physics classroom was of greatest interest. For the rest, it is observed that the topic has consistency over time, that is, during the last 5 years, discussions around the argument have continued to be published consistently.

On the other hand, it has been found that there is a trend in the articles reviewed, since, of the 44 articles, 25 of them declare a qualitative methodology, 15 of them indicate a quantitative methodology, only four declare a mixed methodology and there are 10 of them. articles that do not declare their methodology.

Furthermore, it can be said that several of the selected articles do not indicate the country or territory where the study was carried out. Despite this, those who declare the countries in which the studies were carried out are all from Europe, Africa and the United States. In this sense, it can be noted that the review did not find any articles that refer to argumentation in teacher training that have been published in Latin America. This may be because this region is not interesting to the authors or because the exclusion criteria used for this review ended up leaving out articles from Latin America.

On the other hand, it has been found that there is a trend in the articles reviewed, since, of the 44 articles, 25 of them declare a qualitative methodology, 15 of them say a quantitative methodology, only four declare a mixed methodology.

In the twenty-five articles that present a qualitative methodology, it has been found that the verbs with which they declared their objectives range from compare, investigate or design. From this information it is clear that research on the initial training of teachers in physics, related to argumentation, has a development that points to cognitive levels from application and reaching levels of synthesis. These objectives mainly respond to questions such as: how teachers or researchers intend an argumentative situation in the university physics classroom. They are understood from a procedural space, since when asking how something is done, it is expected that the answer will be with the process that was followed to reach an expected result. In this same group of articles, the preponderance of the case study as a research design has been found, and in that same sense, the observation of classes and the production of arguments in written or oral discursive form by the participants are reported.

In the fifteen articles that are defined with a quantitative methodology, the verbs that guide the research objectives start from a cognitive level of analysis and go all the way to creation, skipping the most basic skills. This shows a maturity in the research topic, as these levels indicate that knowledge already exists and therefore knowledge can be pushed further. Regarding design, what is most repeated in quantitative studies are quasi-experimental studies with a " pre-post-test " strategy and an intervention. The questions that guide this type of study begin with asking about how, but unlike what has been found in qualitative studies, in this type of study it is how the strategy impacts the discourse or how the discourse changes in a given time. type of situations.

In mixed methodology studies, we can find cognitive levels of analysis or evaluation. It is still assumed that argumentation research has development, since the most basic taxonomic levels are not considered, that is, it is not necessary to describe or explore these levels. That is to say, what has been proven is that this seems to be already resolved. In this type of study, the objectives and questions point more directly to the effect that argumentation has on the teaching of physics or to the effect that an intervention has on the way in which it is argued.

The role of the teacher trainer in the argumentative process

When analyzing the articles, the role played by the trainers is vaguely stated. In all of the articles reviewed, the focus is on pre-service teachers who are asked to enter a space of

collective construction of an argument or to respond to a given problem or laboratory situation; It is in this context that it is inferred that trainers have a guiding role for practical activities or are the ones who ask the questions that trainee teachers must answer.

In this sense, in the reviewed literature, constructivist argumentation activities are proposed, with the aim of letting teachers in training build their own knowledge and it is from there that trainers assume a role solely in guiding the process.

If it is considered that the argument can be individual or collective, from its own conception, it is considered a dialogic view of the construction of knowledge. This could have an idea of how science is done and an approach to the Nature of Sciences, but this does not seem to be intentional, so it is left for the individual to assume the construction of an intentional knowledge of how to incorporate the Nature of Sciences in the argumentative process. In this way, trainers participate less than necessary in a process for which trainee teachers are not always explicitly prepared.

Role of teachers in argumentation training

In the articles analyzed it has been confirmed that teachers in training have a predominant role in the argumentative process. In all the selected works, teachers are considered as those who must carry out the action or are the subjects of the study.

In the articles we reviewed, a pattern of searching for a dialogic interaction in the formation of the argumentative process was found. Generally speaking, when teachers are asked to argue, they are usually placed in a group work situation, although it is not always specified whether, prior to group work, they are asked to generate their own arguments. To say that it would have been desirable to use the team learning strategy so that the argumentative processes were more fruitful [16]. Sometimes, in addition to collective work, preservice teachers are asked to generate some type of written production, whether an essay or simply a writing space, and they are also placed in a situation in which they must answer tests or resolve problematic situations and then argue how each of the decisions they make is justified.

How to work on argumentation in the university physics classroom?

In the review carried out, it has been found that when it is necessary to generate arguments or an argumentative situation, Toulmin's argumentative model is normally chosen; This happens in all articles that propose the generation of arguments.

Furthermore, within the 44 selected articles it has been found that in all of them in which the teacher trainer consciously requests an argument and intends to teach how to argue, the Toulmin model is used. Furthermore, in these articles it was found that argumentation was an activity requested by teachers so that their students could apply the model to different situations.

With everything that has been analyzed from the results obtained, questions arise that could be answered in a future review of the literature. Some of the questions that arise are, for example, is there a relationship in literature between the teaching of physics and mathematization? Is there a relationship, in literature, between the teaching of physics and Sense Making?

CONCLUSIONS

In conclusion, it has been found that the relevance of argumentation in university physics teaching is highlighted in the literature. However, it suggests that the relationship between physics teaching and mathematization requires further exploration. The question arises of the possibility of integrating these elements in the initial training of teachers. Furthermore, from the review, it can be concluded that argumentation is crucial not only for learning science, but also for the development of critical thinking skills. This implies that future teachers should be trained not only in science content, but also in how to facilitate and foster argumentation in their own classrooms.

On the other hand, there is a lack of studies from Latin America in the literature reviewed, which could indicate a gap in research on argumentation in teacher education in that region. This could be an opportunity for future research exploring how argumentation is handled in educational contexts in different regions.

It has been found in the literature that the argumentative process proposed by Toulmin's model offers an opportunity to promote Sense. making, this from the collective way in which it is requested to work on the argument in university physics classrooms, is similar to the co-construction of explanations that arise from the Sense process Making.

In that sense, this review opens new questions, such as: Is Sense promoted Making the initial training of physics teachers? Because? Or why not?

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