# The Use of Analogies by Future Physics Teachers in Conducting Supervised Internship Activities

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**Keywords:** analogies, science teaching, supervised internship, physics teaching.

## Abstract

Analogies are frequently used in people's daily lives to relate unfamiliar domain knowledge to everyday knowledge. Because analogies are so common to humanity, using them in teaching and learning is effective for helping students better understand abstract material. In this way, in a supervised internship, we sought to investigate how future physics teachers used analogies during a mini-course on Thermology. Classes were held in two school centres from different contexts: a youth and adult education unit and a high school. The theoretical and methodological references of Pecheutian Discourse Analysis, as well as the models for constructing Teacher with Analogies (TWA) and the Focus-Action-Reflection (FAR) guide, were employed for data analysis. It could be inferred that the future teachers' analogies were drawn spontaneously, while considering the analogies that students were already familiar with.

## Introduction

Analogies and other figures of speech involving comparison are widely used in everyday life, whether in conversations, songs, books, or even science. According to Mozzer (2008) and Curtis & Reigeluth (1984), analogies have likely existed since the emergence of language, and they play a critical role in human cognition, as they are a potential resource of human thought that enables us to modify or acquire new knowledge.

Studies by Bozelli (2005), Curtis & Reigeluth (1984), and Silva & Terrazzan (2009) have shown that the use of analogies as a teaching and learning tool makes it effective for understanding abstract content because people are familiar with it.

Analogies can be confused with other figures of speech such as metaphors, allegories, examples, and similes because they involve comparisons. Often, when we feel the need to explain something to someone, it happens naturally and on its own (Bozelli 2005; Hartje 2017).

Thinking about this spontaneity and the possible challenges it may create for science teaching when not properly planned, this study aimed to investigate how analogies are utilised by undergraduate physics students, future high school physics teachers, during supervised internships. To do this, during their activities for the internship, recordings of a group of undergraduates' classes were used as an analysis corpus in two school units of different

modalities—a technical high school, with regular students and a Centre for Youth and Adult Education (YAE), designed for adult workers that missed their regular schooling.

## Analogies in Science Teaching

Since the early 1980s, numerous researchers have investigated the use of analogies as a teaching tool, as seen in Curtis & Reigeluth (1984), Glynn &Takahashi (1989), Duit (1991), Harrison & Treagust (1993), and Dagher (1995), who have proposed analogy-based teaching models.

Additionally, some researchers have discussed how students and teachers can use this linguistic resource in science teaching (Bozelli & Nardi 2006; Fabião & Duarte 2006; Hartje 2017; Otero 1997; Zambon & Terrazzan 2013).

Analogies can be understood as a comparison between two concepts, one of which the person is familiar with, which we call the "analogue"; the other, unknown, called the "target". To aid comprehension of the target, we establish an analogous relationship by comparing the similarities and differences between the two (Duit 1991; Silva & Terrazzan 2009).

According to Zambon and Terrazzan (2013), an "analogue" is a concept or subject that the interlocutor is already familiar with and may even be knowledgeable about; a "target" is a concept or subject that the interlocutor is ostensibly unfamiliar with but is intended to be understood, and finally, the "analogue relations", which refer to the correspondences between the target and the analogue.

Otero (1997) asserts that one of the factors to consider when choosing an analogue is the visualisation complexity in proportion to the target concept. In other words, when the analogous concept is more complex or less familiar than the target, it can be difficult to understand the meaning of the analogy and, consequently, the target.

This hold true for science teaching as well, according to Bozelli (2005), who investigated General Physics classes in a degree program in Physics and found that analogies used verbally by the professor tended to be unplanned and spontaneous. As the author shows, in some cases, analogies are initiated by the professor and adjusted or even proposed by the students during the explanations.

Otero (1997) argues that the analogies used by teachers during classes are similar to those in textbooks. However, this practice exposes conceptual flaws and a lack of understanding of the analogy due to a lack of planning and information required to delimit the analogies.

Silva and Terrazzan (2009), when examining high school students' familiarity with analogies, highlight a scenario that appears frequently in Brazilian textbooks and is employed by teachers: the case of the "plum pudding" when instructing students on the Thomson Atomic Model.

> This situation should make sense to people in the historical context of its elaboration, that is, in late 19th and early 20th century England. However, in Brazil, this analogue is not usually part of our daily life, that is, there is no plum pudding here, therefore, and it is a cultural issue (Silva & Terrazzan 2009:162).

In this regard, teachers must consider their own sociocultural context as well as that of the students when using analogies as a teaching tool, because, in some cases, analogous situations may not be familiar or known by everyone.

> [...] we reaffirm that the socio-cultural aspects of the region where students live tend to condition the knowledge they usually demonstrate about analogues. [...] It is also recommended to give preference to analogues present in the students' daily lives or suggested by them, during the performance of a didactic activity (Silva & Terrazzan 2009:162).

Several researchers in education have proposed models to formulate analogies to minimise the problems that can arise from a lack of planning when using analogies. The Teaching with Analogies (TWA) model, proposed by Glynn (1991) to formulate analogies in textbooks and adapted by Harrison & Treagust (1993), is one of them.

The TWA model has six stages, namely: i) Introduce the Target Concept to be Learned; ii) Cue the Students' Memory to the Analogous Situation; iii) Identify the Relevant Features of the Analogue; iv) Map the Similarities Between the Analogue and the Target Concepts; v) Identify the Comparisons for which the Analogy Breaks Down; vi) Draw Conclusions About the Target Concepts (Harrison & Treagust, 1993).

According to Harrison and Treagust (2006), due to the realities and dynamics of a classroom, teachers regularly fail to implement one or more steps of the TWA model and therefore suggest the Focus-Action-Reflection (FAR) method to work around this, as shown in Table 1:

**Table 1: The FAR Guide for Teaching with Analogies and Models**

| **Pre-Lesson – FOCUS** | |
|---|---|
| **Concept** | Is the concept difficult, unfamiliar or abstract? |
| **Students** | What ideas do the students already have about the concept? |
| **Experience** | What familiar experiences do students have that I can use? |
| **In-Lesson – ACTION** | |
| **Likes (mapping)** | Check student familiarity with the analogue. |
| | Discuss ways in which the analogue is like the target |
| | Are the ideas surface features or deep relations? |
| **Unlikes (mapping)** | Discuss ways in which the analogue is unlike the target |
| **Post-Lesson – REFLECTION** | |
| **Conclusions** | Was the analogy clear and useful, or confusing |
| **Improvements** | What changes are needed for the following lesson? |
| | What changes are needed next time I use this analogy? |

Source: Harrison and Treagust (2006:21).

The guide proposed by Harrison and Treagust (2006) can be used by teachers as a way to plan and reflect on the analogy to be used in class. It is divided into three moments: before class (planning), during class (execution) and at the end of class (reflection). Thus, it enables the

teacher to take into account the socio-cultural context of the students and to carry out a critical reflection of their practice.

## Pecheutian Discourse Analysis

Since we began with the inherent connection between language and analogies (Curtis & Reigeluth, 1984) and from the relationship between language and the principles of the Pecheutian Discourse Analysis (DA), we decided to use (DA) as a theoretical and methodological reference for this research.

The Pecheutian Discourse Analysis (DA) was developed in France by Michel Pêcheux and his group. In Brazil, professor and researcher Eni P. Orlandi was the main pioneer of this movement. According to Orlandi (2003), DA arises from the intersection of three domains of knowledge: Linguistics, Marxism, and Psychoanalysis. She states that language is not transparent and unique, meaning it does not transfer directly "term-to-term" from one interlocutor to another, as the production of meanings occurs through the combination of language with individuals' history.

In this sense, DA aims to highlight the effects of meanings produced by discourses. Moreover, according to Orlandi (2003), there are mechanisms that condition the production of discourses: i) the *relationship of meanings*, where every discourse is related to other discourses; ii) the *mechanism of anticipation*, suggesting that every subject has the capacity to place themselves in the position of the one who "hears" their words, allowing them to anticipate what the listener "expects" and the effects of meanings that may be produced in interlocutors; and iii) the *relationship of force*, which asserts that the effects of meanings are determined by the position the subject occupies. For example, the teacher's speech is worth (means) more than the student's (Orlandi 2003).

In the context of this research, DA as a theoretical and methodological device will be used to analyse the analogies made by future teachers during supervised internship classes in schools, aiming to identify the effects of meaning and the mechanisms of discourse production.

## Research Methodology

To collect the data in this research, we looked at the class recordings made by a group of physics undergraduates as they conducted activities for their supervised internship in two different types of educational settings: a technical high school with regular students and a Centre for Youth and Adult Education (YAE). These two cohorts were selected because the sample of students comes from very different contexts and we aimed to analyse the use of analogies in different ambiences. The high school students are adolescents (15 to 17 years old, so, in the regular time of schooling), while the YAE students are adults who left school and later returned as adults. The YAE students, in general, are workers who attend school in evening classes.

In the undergraduate course analysed in this research, future teachers develop and gave lessons in a mini-course known as “The Other Side of Physics” in the final discipline course of the supervised internship.

The short course's proposal was to create an alternative method of teaching physics that differs from what is typically found in classrooms, whereby undergraduate students prepare the classes using the learnings from their entire initial training. The internship is an important part of the future teachers’ curriculum programmes that allows to integrate initial training and the

elementary or high school ambience and, thus, provide a space for a final synthesis of the degree, giving the future teachers the opportunity to critically reflect on the social practice of educating and the legitimation of the school reality (Pimenta & Lima 2010).

With the permission of all research participants (high school students, undergraduate students, and professors and graduates at the university), the research corpus was created using documents submitted by the undergraduates and audio-visual recordings of the lectures (approved by the School of Science's Ethical Committee – consent form #02084918.2.0000.5398 – Plataforma Brasil) (Parma, 2020). The participants were 17 undergraduates in the Internship discipline during the research period. They were divided into six teams, in charge of developing the following Physics contents for the mini-course: Mechanics, Astronomy, Thermology, Optics, Electromagnetism, and Modern and Contemporary Physics

In this paper, we chose to analyse the classes taught by the team responsible for the Thermology content because all classes were planned and developed with practical activities, making them dynamic and interactive. Three undergraduates comprised the team: Jonas, Ronaldo, and Teodoro. The names are not real; they were chosen in order to maintain their anonymity, according to the ethical compromise cited before.

To investigate the proposed research question, we first sought to raise, in recordings of the conducting activities, the analogies made by the undergraduates, showing the structure of the analogy in detail, that is, highlighting which were the analogues, targets, and the analogical relations between them.

## Data analysis and discussion

Nine analogies were identified when raising the analogies present in the classes taught by the Thermology group in the two schools: five from High School (HS) and four from YAE.

The first identified analogy was performed at YAE and attempted to compare the movement of a flame (analogue) with the agitation of molecules (target). To make this connection, Ronaldo used the visual resource of animating a moving flame and associating this movement with the high agitation of the molecules.

> *Ronaldo: There the molecules were agitated, desperate, on fire! You see it there and you throw water. You reduce the agitation with the water, which has the less agitated molecules... thus coming into balance.*

The analogical relationship that the undergraduates seeks to achieve is the idea that, when mixing a lower temperature body with a higher temperature body, the bodies tend to come into thermal equilibrium. However, this analogy is problematic, since it is not only the agitation of the molecules of the higher temperature body that decreases. Molecules in the lower temperature body tend to increase as well. Not only that, but adding water to a fire conceptually stops the combustion/chemical reaction rather than just bringing it to thermal equilibrium. This is because fire is a chemical reaction.

This is a conceptual blunder that might cause problems in terms of scientific education; however, via the critical reflection that undergraduates perform during the stages of the Supervising Internship, they noticed the mistake and did not use this comparison when they went to teach again the same classes for HS.

Another example used at YAE was the similarity ratio of a thermal insulator to an electrical insulator in the description of the thermal conduction process. To further develop the analogy, Jonas attempted to utilise insulating tape, a common and recognisable object in people's daily lives, to repair electrical cables in an improvised manner.

Based on the experiment, one of the YAE students concluded that the iron bar is a thermal conductor and the wooden bar is a thermal insulator by drawing an analogy between the functionality of the thermal insulator (target) and that of the electrical insulator (analogue). This demonstrates that, in this case, the analogical link worked well in the context of the class.

Additionally, Jonas' consideration of the students' context throughout the analogy activity can be observed, as Silva & Terrazzan (2009) have emphasised. Through the mechanisms of speech production, it allowed them to put themselves in the place of the interlocutors and anticipate the effects of meanings (Orlandi, 2003), since they are adults and that many of them work and may be more familiar with objects that insulate electricity, such as the case of insulating tapes. During the discussions in the university, the undergraduates were asked to think about possible analogies that they could face during the classes, especially in the case of YAE, where students are adult workers and have more life experience than those of HS students. In this case, however, it was not possible to figure out if Jonas had planned this analogy or just happened spontaneously.

This is made quite evident when high school teachers employ the same analogy but focus on the idea of an electrical insulator rather than using an analogy involving electrical tape. Our assumption is that HS students are more accustomed to the concepts and material covered in class and in textbooks.

We further stress that the analogy that was generated spontaneously during classes at YAE was retained and adapted to the HS context, as indicated by the FAR guide during the reflection phase (Harrison & Treagust, 2006).

The next analogy found in the YAE class records were related to the concept of density. In this analogy, the undergraduate is attempting to represent the expansion and contraction of water (target). For example, he used the density of a piece of chalk in his hand as an analogous condition to explain the properties of mass and volume, envisioning, with the students, what would happen to the density of the chalk if it were compressed or dilated.

> *Jonas: Like this chalk, for example, it has a certain mass, which is so many grams, and it has this volume here, which is its size, right? If I take and compress this here, to a much smaller size, it will continue to have the same mass, but it will have a smaller volume, so its density will be greater. [...] Now if I take this chalk with the same mass, and increase it, I'll make it big, but with the same mass, it will have a lower density. The same thing happens with water, if I increase the temperature of the water, the density... it's as if I increased the volume, that is, the molecules are a little further apart, when that happens, it becomes less dense and it tends to go up, okay?*

The concept of analogue falls outside of Harrison & Treagust's (1993) requirements. The limits of the analogy were not well established, as seen in the fifth step of the model adapted from TWA, because chalk is a solid that breaks easily, so its compression and expansion are abstract to be observed with the naked eye, as shown by teacher, making the similarity between the target and the analogue tricky.

Two analogies were identified in YAE classes to address the topic of heat transmission via convection. The first attempts to match the analogous concept of convection of boiling water in a pan with the idea of convection of cool air coming out of an air conditioner.

Prior to the analogy, undergraduates carried out an experiment to show the convection of hot and cold water. As a result, when Teodoro asks the students why air conditioners are mounted high on the wall, the students' responses were consistent with the notion that ‘hot air goes up and cold air goes down’, as explained during the class.

> *Teodoro: Can you say what you think, why is the air conditioning up there and not down here?*
>
> *Alana: Because the cold air will go down.*
>
> *Gustavo: And the hot air will rise.*
>
> *Teodoro: Yes! Cold air, or cold water, is denser, so they go down. Hot air, hot water, on the other hand, is less dense, so it will rise.*

Due to the previous practical activity and explanation of how the thermal convection of boiling water inside a pan works, the limits of the analogy were well established; in other words, the students were already familiar with the concept of convection from class.

The undergraduates then used the results of that same thermal convection experiment to draw an analogy between the climatic phenomenon of thermal inversion (target) and what happens with the water (analogue).

> *Jonas: This explains the very important phenomenon that happens in big cities [...] thermal inversion, problem with air pollution and everything else, that's what's happening [...] the air close to the ground is colder than the air above, so this air is not circulating, just like the cold air below and the hot air above, they don't mix, they don't change positions, the pollution is trapped down there. In normal situations, when there is no thermal inversion, the hot air is below, the sun hits it, it heats the ground, and the ground heats the air, and the hot air rises.*

Through the practical activity above cited it was possible to visually observe the effect of thermal inversion. As a result, the analogy can be established coherently. Based on the TWA model, there was a contextualization of the analogous concept through an experiment and contextualization of the target concept through an example.

However, when the same analogy is used in HS, some students describe the results the analogy even before the undergraduates finish relating the experiment to thermal inversion. When asked how they came up with this conclusion, students quickly respond that water is analogous to air. As a result of the information presented by the undergraduates and the experiment, the students construct an analogous relationship.

The other two analogies happened among HS students at the technical college and have no direct connection with the content of Thermology. The first is about temporal flow, and the second concerns on physical concepts with many variables.

When one of the students asks the undergraduates if it is possible to go back in time, Jonas spontaneously draws an analogy between the temporal flow (target) and a river’s current (analogue).

> *Jonas: Because time is continuous. You can only follow it, it's like a continuous flow. Imagine it as if it were a current, you can't swim against it, time you can't go against it, you can go forward, you move forward. You cannot go back because that time has passed.*

As emphasised by Duit (1991) and Harrison & Treagust (1993) in the TWA model adaptation, the analogy must be understood in terms of similarities between the target and the analogue. There is a point in this last analogy analysed, though, where it becomes difficult to grasp the idea of time.

According to Harrison & Treagust's (1993) adaptation of the TWA model, whose fifth step is "identification of the limits of validity of the analogy used", this analogy's limit needs to be reconsidered because, despite its difficulty, it is possible to increase water current flow, which is not the case with time.

In relation to the comparison between a city map and a physical concept with many variables, Jonas also improvised the following analogy:

> *Every physical phenomenon that we are going to study always has much more behind it than we can take into account. What we have in Physics is not the whole city, we get the map. With the map, you can more or less get an idea of where you are, but it won't indicate where there's a hole in the road or where it's blocked. So that's what physics is, it's a map, it guides more or less to do that, the path is more or less this, but it won't give you all the answers about everything you want to find. For you to consider the whole, everything behind it, you would look for the rest of your life and not come up with an answer.*

In this discursive excerpt, with the help of a city map as an analogue, the undergraduate attempts to explain the scenario of physical phenomena in a panorama. This analogy fits expectations in accordance with the TWA model's steps because he made sure the students understood the analogous connection between the target and the analogue (Harrison & Treagust, 1993).

Additionally, even if briefly, Jonas discusses the parallels and dissimilarities between the target and the analogue—in accordance with the FAR Guide's recommended actions (Harrison & Treagust, 2006). It is the responsibility of teachers to evaluate the relevance, the positive and negative points, and what should be kept and added to the analogical relationship used in class during the reflection process.

## Final remarks

We can consider that, even though all the analogies were similar from one school unit (HS) to another (YAE), it is noticeable, through the lesson plans previously prepared and in the university reflections meetings, that a large portion of them were not planned in advance. Only the analogy about thermal inversion was elaborated with the help of the practical activity, in order to contextualize and make the topic familiar.

Due to this lack of prior planning, certain analogies showed conceptual mistakes and difficulty in following a clear and objective analogical relationship, such as the analogies used to explain chemical equilibrium, temporal flux, and current.

However, through reflection and because they concluded that the analogy was not clear, helpful or unambiguous, the teachers moved on and did not take it to another school. Contrary to the

analogy between thermal insulator and electrical insulator, which, even though it was performed spontaneously, its clarity and usefulness were determined, and for this reason it was added to the HS lesson plan.

Through the mechanisms of discursive processes, such as the anticipation mechanism (Orlandi, 2003), the undergraduates put themselves in the students' shoes and seek to adapt the analogy and test the students' familiarity with the analogues, taking into account their socio-historical contexts. Likewise, it should be mentioned that in the YAE, the undergraduates were more careful and provided a more detailed explanation, as for most of those interlocutors, the content had never been seen before. In HS, however, the explanations were more direct, as it was considered that the students had already studied this content in their regular classes, as observed in the videotaped classes recording.

Therefore, in consonance with other cited works, prior planning of analogies is of great importance for the teacher, as it will provide them subsidies to carry out a mapping exercise, allowing for empathy with their interlocutors' and identification of their familiarity with the analogues. In this case, post-analogy critical reflections were also crucial because it allowed to highlight the positive and negative aspects of the analogy as well as the changes that have occurred. The experience that these undergraduates had were very important due to the fact that these reflections will be useful for their future teaching practice.

In conclusion, through the effects of meaning mobilized during the speeches promoted by the future physics teachers in their analogies, this study demonstrated that undergraduate students mainly used analogies spontaneously. We finally noted, in the analysis of the university teaching training programme, that there is no guidance regarding the use of analogies and other figures of speech as teaching tools. Thus, we emphasise the significance of these studies and discussions about the application of analogies in science instruction, so that we can better prepare future Physics teachers.

## Acknowledgments

The authors thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPq) in Brazil for financial support. We also thank the undergraduates and students of the schools for agreeing to participate in this research.

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