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DEVELOPMENT OF A FORMATIVE SEQUENCE FOR PROSPECTIVE SCIENCE TEACHERS: THE CHALLENGE OF IMPROVING TEACHING WITH ANALOGIES THROUGH THE INTEGRATION OF INFOGRAPHICS AND AUGMENTED REALITY

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Abstract

Teachers often use analogies to introduce unfamiliar or complex concepts. However, several studies have found that their knowledge on how to use them is limited or superficial. Similarly, the integration of technological resources in the teaching-learning processes is not always carried out efficiently, which evidences the need to improve teachers' digital competence. This paper provides a formative sequence on the use of analogies in teaching through mediation of technological resources, implemented in the context of the initial training of secondary education teachers. The results show a positive assessment by the students, a change in their perceptions on the subject and some progress in their classroom proposal designs. The conclusion is that it is necessary to train future teachers to deal with common teaching problems in a reflective, comprehensive and innovative way, which will undoubtedly be one of the challenges of education in the 21st century.

Keywords – Teacher training, Analogies, Augmented reality, Infographics.

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1. Introduction

Experimental science teaching has undergone major changes, as students find it increasingly difficult to acquire knowledge and transfer it to daily situations (Nieda & Macedo, 1997). Likewise, teachers must not only know how to teach a specific subject, but they must also find ways to connect with students, who are more and more heterogeneous (Martín, Prieto & Jiménez, 2015). This means that teaching must include processes and situations specific to the students' social context, thus favoring their involvement (Kolsto, 2001; Ratcliffe & Grace, 2003).

Additionally, many researchers highlight the importance of scientific literacy, defined as "teaching science (knowledge contents and processes) and teaching about science (contents about what science is)"

(García-Carmona, Vázquez & Manassero, 2011: page 403), in order to overcome the aforementioned difficulties of understanding. It is therefore evident that there is a need for both students and teachers to acquire appropriate notions and approaches about what science is, how it is constructed, how it works and, moreover, how it relates to society (García-Carmona et al., 2011). To this end, it is important that the school community, as well as the general population, have the tools to understand and manage the science that surrounds them (Aguilera-Morales, Vílchez-González, Carrillo-Rosúa & Perales-Palacios, 2021).

In line with the above, science teaching processes need to include strategies to promote student interest and encourage critical and reflective thinking (Unas, 2014). For this reason, this type of didactic research is increasingly focused on studies of specific didactic resources, their application in the classroom and their usefulness in motivating students.

One of said didactic resources are analogies, comparisons of structures between two domains (Duit, 1999) – a familiar or "analog" domain and an unfamiliar or "topic" knowledge (Raviolo, 2009). The use of this resource as a didactic strategy allows not only to get students involved from their prior knowledge (Raviolo & Lerzo, 2016), but also helps them to develop and learn scientific models and to acquire imaginative skills and abilities (Oliva, 2011). It also facilitates the organization and contextualization of information, thus enhancing meaningful learning (Raviolo, Aguilar, Ramírez & López, 2011).

However, the effectiveness of analogies depends on certain factors that teachers must master before including them in their lessons. Regarding the analogy itself, it is important to know and manage all the relationships and comparisons that can be made between analog and topic (Raviolo & Lerzo, 2016). In addition, knowing the characteristics of the group of students for whom the analogy is intended is critical (Iglesias, 2010), as well as the prior knowledge they start from, and their insights into what is happening in their surroundings and in the classroom must also be taken into account (Rubio, Sánchez & Valcárcel, 2018).

Besides, teaching has become a complex and challenging task, since the expectations on education have increased significantly (González, 2009), partly due to scientific and technological development (Unceta, 2008). The use of information and communication technologies (hereinafter ICT) has become one of the cornerstones of teaching and how it should be structured (López, 2008). In view of this, there are different beliefs, resistances, and even negative activities, generally caused by the lack of ICT training (Arancibia, Cabero & Marín, 2020) and especially if we take into account the striking difference between the digital competence that teachers are required to have and the one they actually have (Falcó, 2017; Padilla 2018).

Nevertheless, from the beginning of technological development, teachers have been interested in its application and development in the educational sphere (Sánchez-Tarazaga, 2016). Therefore, from the standpoint of initial teacher training, it is necessary to enable future teachers to acquire learning experiences (Ibernón, 1989) and develop their digital teaching competence (Esteve-Mon, Gisbert-Cervera & Lázaro-Cantabrana, 2016) so as to enable them to design and implement learning sequences that are truly meaningful for their future students. The trend today is teacher training supported by informed decision-making and the ability to analyze and evaluate the information received, thereby giving great relevance to the teachers' own view of what they are teaching and how they do it (Martín et al., 2015).

Considering the above, and in the context of the Master's Degree in Secondary Education Teacher Training, specifically in the field of experimental sciences, some questions arise:

1. How should science teachers use analogies?
2. How can students apply what they have learned to a classroom design?
3. What are students' perceptions of analogies and ICT?
4. How should future teachers be trained in the integration of ICTs in the teaching-learning processes?

2. Method

2.1. Objectives

In order to answer these questions, two objectives were set:

a) To design, implement and evaluate a formative sequence for prospective teachers on the use of ICT-mediated analogies in teaching-learning processes.

b) To assess the change in students' conceptions and beliefs about the use of analogies.

2.2. Context and Participants

An intervention proposal directed to the initial training of secondary school teachers was designed and carried out in the subjects of Learning and Teaching of Physics and Chemistry and Learning and Teaching of Biology and Geology of the Master's Degree in Secondary Education Teacher Training offered by the University of Laguna, during the 2021-22 academic year.

A total of 31 students participated – 16 female and 15 male (Table 1). According to age, 16 subjects were 25 or under, 11 were between 26-32 years old and 4 were over 34. The mean age was 27.3 years, ranging from a minimum of 22 to a maximum of 43 years.

	Male		**Female**	
Total	15	48.4%	16	51.6%

Table 1. Sample of participants

2.3. Theoretical Fundamentals

In designing the proposal, the following theoretical aspects were observed:

- The considerations of Oliva, Aragón, Mateo and Bonat (2001) regarding the conceptions and beliefs of (practicing) science teachers about the use of analogies and Oliva (2008) regarding the desired professional knowledge of science teachers about analogies as an educational resource.
- The considerations of Gisbert, González and Esteve (2016) regarding digital competence and digital teaching competence (hereinafter, DTC).
- Previous works on didactic sequences and ICT resources (Aragón-Méndez & Oliva, 2020; Aznar, Romero & Rodríguez, 2018; Fernández & Marrero, 2013; Durukan, Artun & Temur, 2020; Gómez & Lavín, 2016; Maquilón, Mirete & Avilés, 2017).

The following consideration was also taken into account:

Learning with analogies is based on the understanding of the relationships between the scientific topic (hereinafter, T) and its analog (hereinafter, A). For such purpose, learners make use of mental models, and different analogical models may even appear (Duit, 1991). These models influence the limitations or risks involved in the use of analogies. Thus, for example, students may interpret an analogy in a mechanical way without grasping its substance or simply misunderstand it, resulting in the appearance of possible conceptual errors (Orgill & Bodner, 2004). Therefore, based on previous research in science education (Hong, Hwang, Liu, Ho & Chen, 2014; Kearney, Treagust, Yeo & Zadnik, 2001; Zacharia, 2005) showing that the use of ICT substantially improves scientific explanation, this paper proposes the use of digital media as a means of mediating between the different mental models that students can construct. That is, ICT resources can assist in elaborating and changing models (Figure 1), from the simplest ones (where only components are recognized: first model) to more complex ones (with components and relationships among them: second and third models), facilitating the transition between A and T.

It should be noted that, although being an important resource for science teaching, the use of analogies, whether analogical or digitally mediated, does not guarantee *per se* a truly meaningful learning by students. Nor can we ignore the difficulties that teachers encounter in integrating ICT into the teaching-learning processes, especially considering the shortcomings or weaknesses in their digital teaching skills, hence the importance of this subject in the initial teachers' training (Cabero-Almenara & Martínez, 2019).

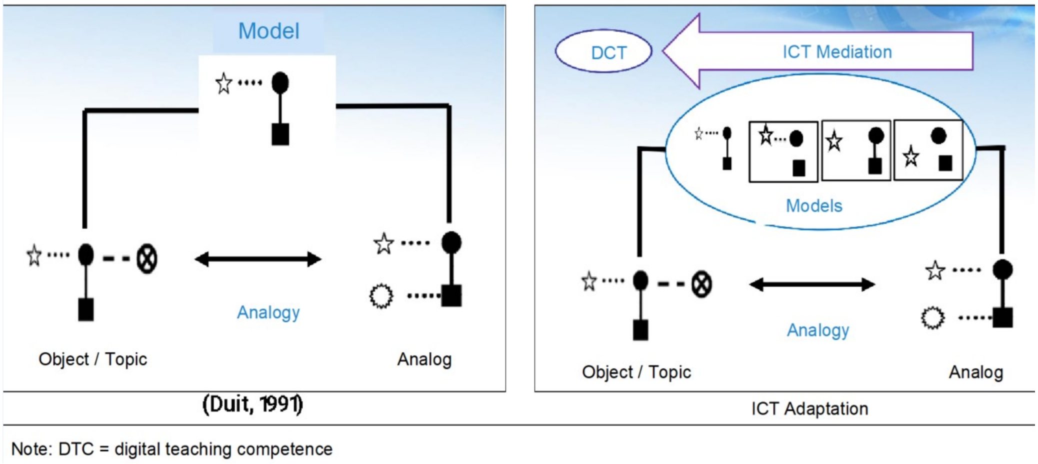

Figure 1. Adaptation of Duit (1991) to an ICT-mediated approach

2.4. Description of the Proposal

The purpose of this didactic proposal was to train prospective teachers of experimental sciences in the use of analogies in the teaching-learning processes, as well as to provide them with new digital tools that favor a better interpretation of such analogies and, therefore, a didactic transposition that is consistent with the theoretical fundamentals used.

For this, a didactic sequence based on varied methodologies and mainly constructivist in nature was proposed, in which the general scheme of intervention was based on the students' conceptions and ideas, allowing educators to guide the following activities by adapting them to their responses. Throughout the sequence, brainstorming, questions on opinions and discussions were proposed to facilitate the exchange of information, in an attempt to create a collaborative, reflective and eminently practical type of learning. At the end, a final formative evaluation was carried out so that students could analyze their own learning and at the same time evaluate the training proposal.

Accordingly, the didactic sequence was organized in three sessions of 4 hours each (Figure 2), structured with initiation, development, and synthesis activities.

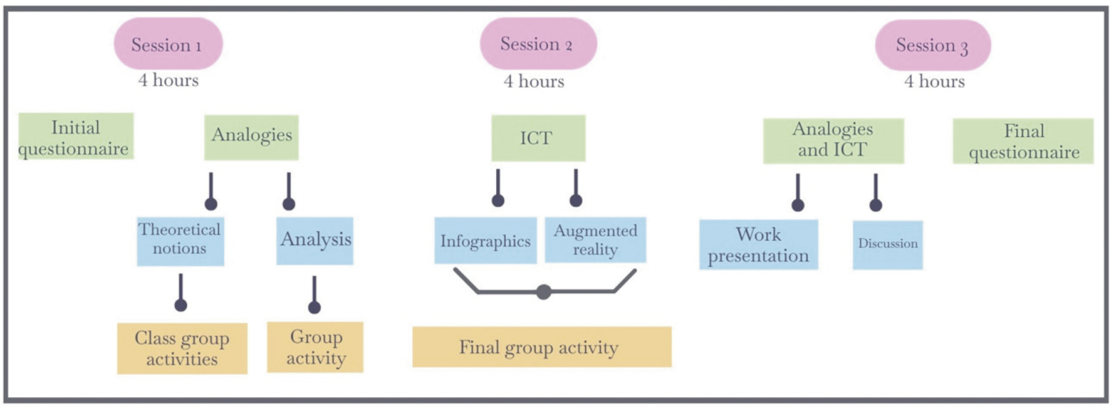

Figure 2. Development of training proposal

2.4.1. Session 1

The goals of the first session were:

- To determine the students' knowledge of analogies and their usefulness
- To introduce analogies as a didactic resource
- To analyze examples of analogies in a practical way, in terms of their structure, their adequacy and their limitations.

For this purpose, a sequence of activities was designed, organized as shown in Figure 3.

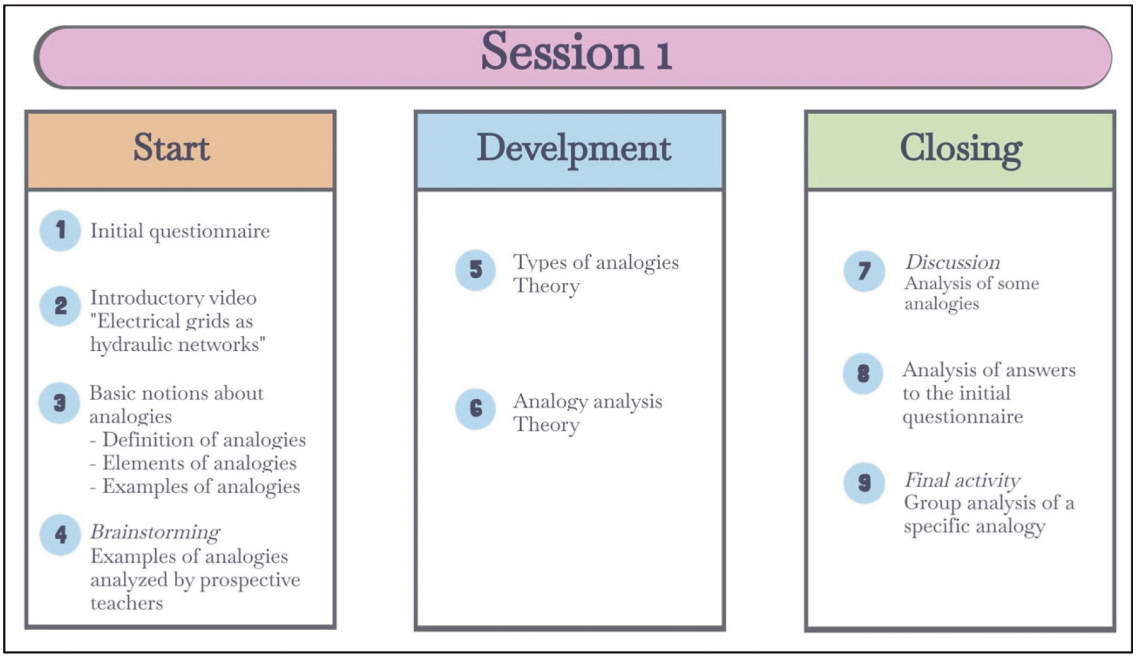

Figure 3. Development of session 1

The session began with a questionnaire aimed at determining prospective teachers' prior conceptions about analogies. Once completed, by means of different activities, the educators presented some common analogies in the teaching of science (magnets/gravity, fishing net/crystalline lattice; solar system/Bohr's atom; hydraulic network/electrical grid; factory/cell; calendar/periodic table) and elaborated on the concept of analogy and its differences with metaphors, similes, examples and models. Table 2 provides a more detailed description of the development of activities 1 to 4.

Activity		Development
1	Questionnaire	Individually and using the GoogleForms tool
2	Electrical networks as hydraulic networks video	Comparison between the hydraulic networks of ancient civilizations or city streets and an electrical grid. Students were asked to detect and analyze these comparisons.
3	Basic notions	Theoretical activity in which the contents associated with analogies were taught: the concept of analogy, metaphor, simile, example, and model.
4	"Brainstorming"	Practical activity in the class group where simple examples of analogies were discussed.

Table 2. Activities at the beginning of session 1

In the development phase, theoretical aspects were implemented, with examples of analogies and a brief activity on each of them. Afterwards, an analogy analysis method was presented (Marrero, Elórtegui, Tejera & Fernández, 2008), which allowed a much more detailed study of the resource. To introduce this technique, the following slide (Figure 4) was shown to the students, schematically outlining the procedure to be carried out. First, the analog and the topic should be announced. Then, the components and attributes of each one of them are searched for separately. The next step is to determine the relationships, also separately, between the components and/or attributes found. Finally, a comparison of all these elements of the analog and the topic is made. This comparison can be used to highlight the coinciding and differential aspects, making it possible to assess the adequacy of the analog for understanding the topic, as well as its limitations.

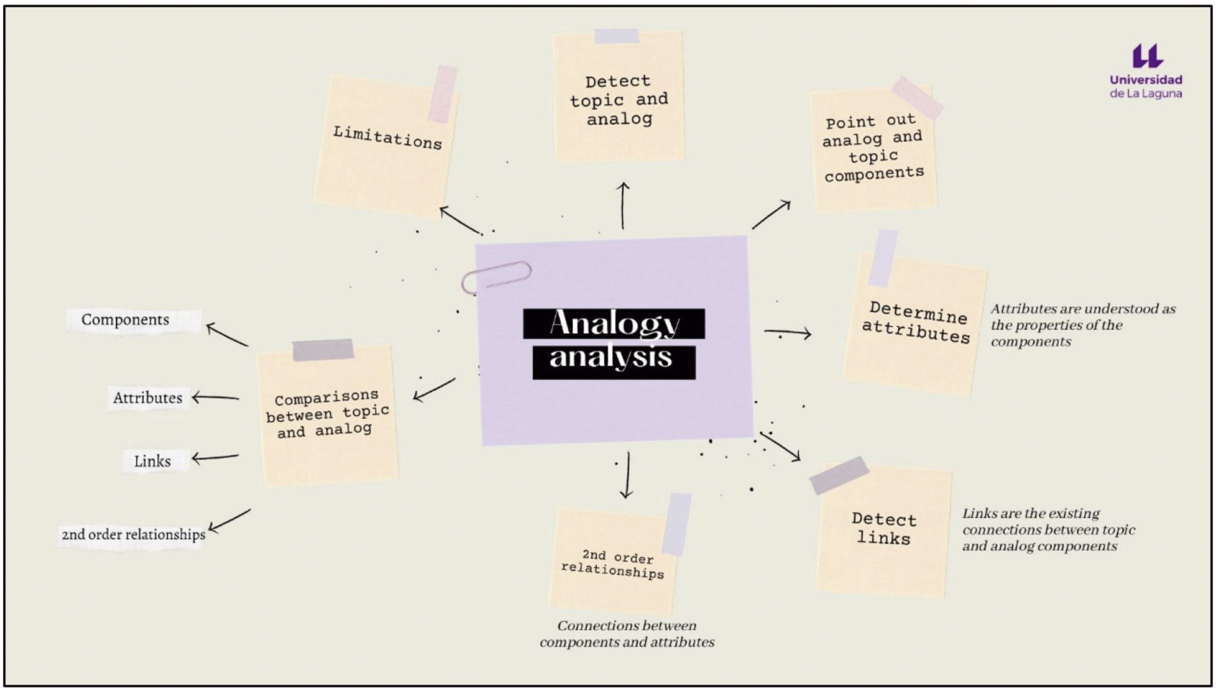

Figure 4. Analogy analysis

This technique was used for the analogy between Bohr's atomic model and the solar system, as proposed by the authors. In this way, the students had the meaning of each of the steps of the analysis exemplified and were able to perform an analysis of another analogy autonomously.

In the closing phase, the three activities detailed in Table 3 were solved.

Activity		Description	Analogies	
1	Discussion – Analysis of analogy statements	Analysis of analogy statements, discussing specific examples in the class group, with the corresponding analog and topic	• Juggling and balance in blood transport • Camera and eye • Circulation of cars and electric circuit • Crystal lattice and knots	
2	Detailed analysis of an analogy	Small-group analysis of an analogy using the suggested analysis technique	Biology	Factory and cell
			Physics and Chemistry	Periodic table and calendar

Table 3. Closing activities of session 1

2.4.2. Session 2

The goals of the second session were:

- To analyze analogies in terms of their limitations.
- To introduce the Teaching with Analogies (TWA) model

- To introduce ICT as a solution to possible difficulties associated with the use of analogies.

As in the first session, this one was also structured in three phases (Figure 5).

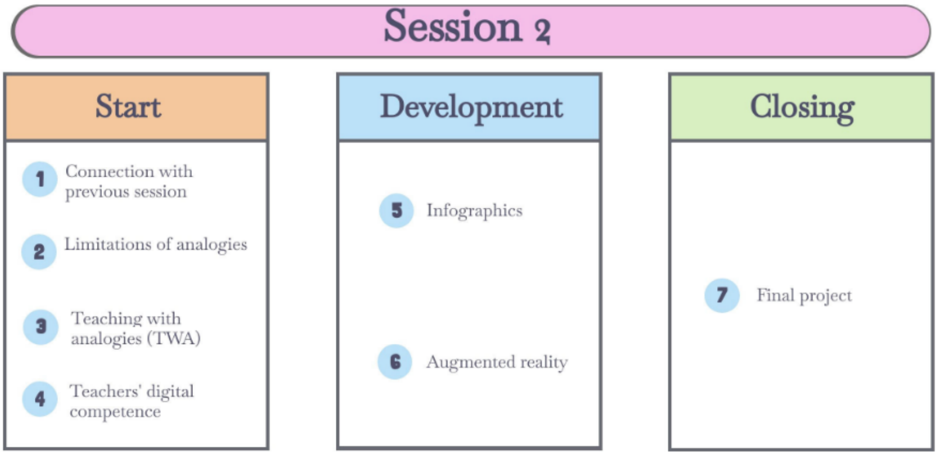

Figure 5. Structure – session 2

The session began a summary of the previous session. Then, the possible limitations of analogies were introduced in a theoretical fashion, some examples were proposed for analysis on the basis of this criterion and, finally, there was a discussion on the implications of analogies.

Next, the Teaching with Analogies (TWA) methodology was presented and how this strategy should be used in the classroom, determining in a group and reflective process the steps to be followed. To conclude this phase, theoretical aspects related to analogies (functioning of an analogy and mental model) were taught in connection with the authors' proposal for the incorporation of ICTs. That is, as part of the steps determined for the use of analogies in the classroom, it was intended that teachers undergoing training would determine in which of them the use of digital resources would be appropriate and in what form, so that the students could construct consistent and adequate models through these resources. To facilitate and enhance the participants' DTC, the European Framework for the Digital Competence of Educators "*DigCompEdu*" (Redecker & Punie, 2017) was presented, and the different domains and competences were analyzed.

In the development phase, a set of possible technological resources (simulations, infographics, augmented reality and virtual reality) that could be used for the TWA were presented and their limitations were analyzed. The use of infographics and Augmented Reality (AR) was then explored in more detail. Some details are shown below:

A) Infographics

An infographic can be defined as the combination of visual effects that provide a graphic display of the information to be conveyed (Vilaplana, 2019). It is presented to the students as it combines the visual with the informative, allowing them to overcome some of the obstacles that appear with abstract scientific concepts. Thus, a self-made infographic is presented (Figure 6) in which the results of the analysis of the analogy between the solar system and Bohr's atomic model are collected.

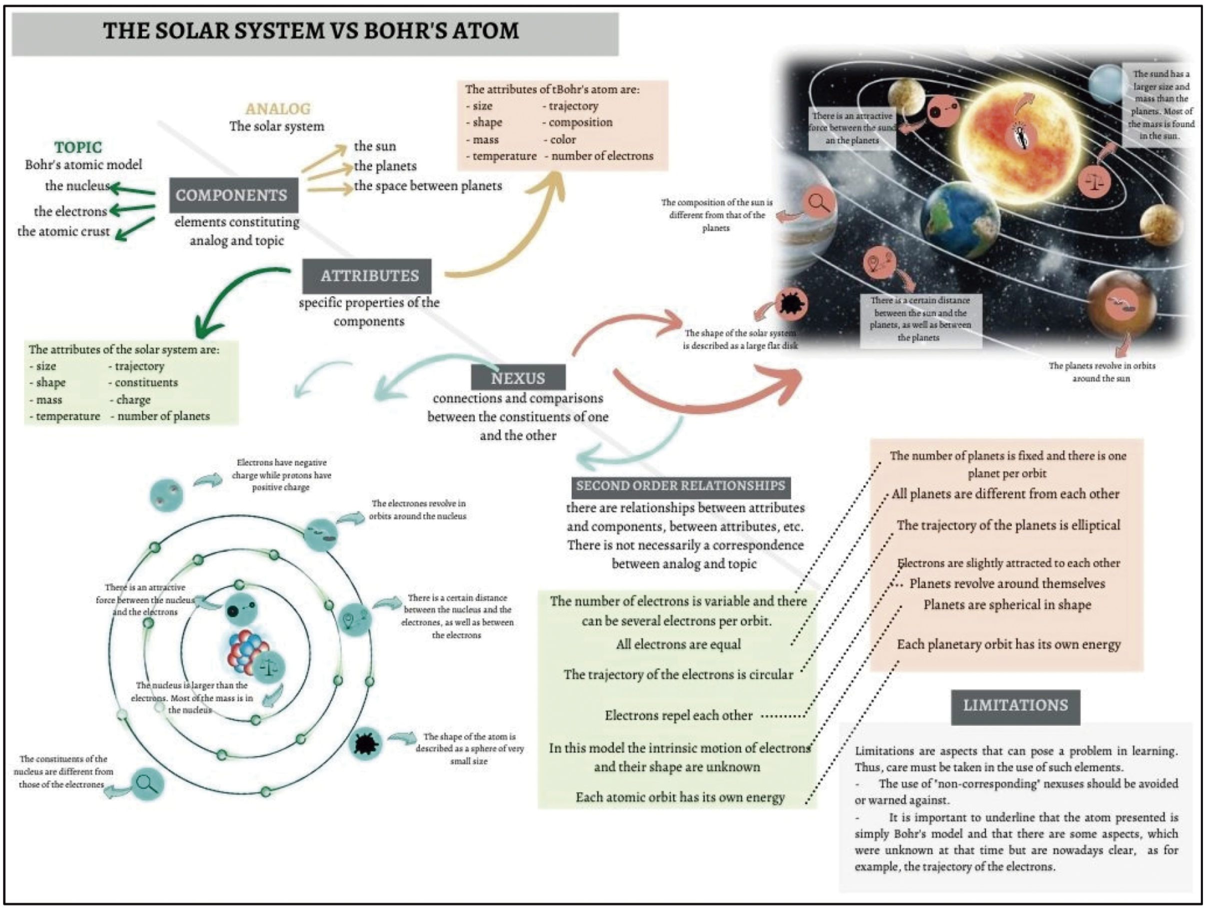

Figure 6. Infographic Solar System-Bohr atom

B) Augmented Reality

Augmented Reality is defined as the "artificial enhancement of the perception of reality, by means of virtual information" (Maquillón et al., 2017: page 185). It can be interesting in teaching-learning processes, since it is based on the representation of objects in 3D and also on the interaction with the viewer, which is appealing to students (Agudelo, 2005). Likewise, it is considered a great didactic resource, since by integrating the knowledge that learners must acquire in their real and physical settings, it combines the active and the constructivist learning methodologies (Maquillón et al., 2017).

To further explore the use of AR in experimental sciences, the students were provided with examples of applications that allow them to work either through marker tracking or even through localization. For this, the same scheme was followed for each resource: the functioning of the application was presented, then different analogies represented by the resource were shown and, lastly, the usefulness of the resource was discussed.

Some of the AR applications initially presented were: *Zap*par (https://www.zappar.com/), Hope (https://www.hope.com.pe/) and AR Atoms (https://mas-menos.net/atomos-ra/) which are based on token scanning with AR technology. To make use of these applications, the device must be placed on the token and additional information will appear digitally on the device screen. Figure 7 shows the use of *AR Atoms*, where the appearance of the oxygen atom and different information can be observed when scanning an AR token. Once the application is downloaded, the scanner option appears directly on the device screen. Users simply need to point the camera at the token and the AR information is automatically displayed. Its use in the teaching-learning process provides an approximate view of the topic (atom), so its use together with the infographic in Figure 6 helps to improve the comparison between the solar system and the atom.

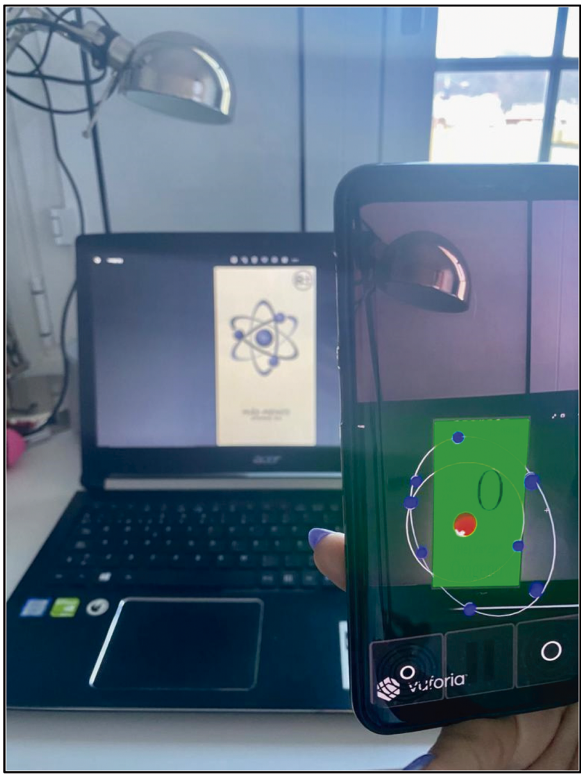

Figure 7. Use of *AR Atoms* - Oxygen Atom

Next, the Augmented Class application (http://www.augmentedclass.com/), was shown, which allows students to create their own AR by choosing a main image to which text boxes, images, links, etc. are added as additional information.

Finally, the session ended with the students completing a final project to put into practice what they had learned, which is described in detail in the following section on "tools for gathering information". Some examples of the final work presented by the students are shown in Table 4.

Analogies		**ICT Resources**
Topic	**Analog**	
Eye	Camera	Videos: https://www.youtube.com/watch?v=OGqAM2Mykng https://www.youtube.com/watch?v=_TtA8iVA9zc
		My Eye Anatomy Application (https://play.google.com/store/apps/details?id=com.visual3dscience.Eye&hl=es&gl=US&pli=1)
Photosynthesis	Bread making	Mozaik Education (https://www.mozaweb.com/es/) Canva (https://www.canva.com/es_es/) Kahoot! (https://kahoot.it/)
Antigen-Antibody	Key-Lock	Pages with multimedia material, information and self-assessment: - Bionova.org - Liveworksheets.com AR applications - Roar AR: (https://theroar.io/) - Metaverse - Augmented Reality (https://www.corporate-metaverse.com/?gclid=Cj0KCQiA1ZGcBhCoARIsAGQ0kkqidmpqKNeiQMVDSDfAelKcfRtg8KBxle-IRDmtrjimGS36SjvU2kkaAsxdEALw_wcB) - Vuforia Developer Portal (https://developer.vuforia.com/) - Geo Layer: Realidad Aumentada (https://aescripts.com/geolayers/) - Zappar (https://www.zappar.com/)

Analogies		ICT Resources
Topic	**Analog**	
Cell	City	Mentimeter (https://www.mentimeter.com/) Kahoot! Liveworksheets Canva Prezi (https://prezi.com/es/)
Cell nucleus and DNA	Library and Books	Augment (https://agmt.it/m/592eSW33) Vídeos: https://www.youtube.com/watch?v=4zHU9Tky-nk&t=48s https://www.youtube.com/watch?v=HGDTyw-517k
Chemical substances	Lego	Tinkercad (https://www.tinkercad.com/) Mecabricks (https://www.mecabricks.com/es/workshop). Simulations (https://phet.colorado.edu/sims/html/balancing-chemical-equations/latest/balancing-chemical-equations_es_ES.html)
	Sticks and balls	Virtual modeling kit (https://chemagic.org/molecules/amini.html)
Redox reaction	People passing balls to each other	Augmented Class!
Activation energy	Bicycle going uphill	Animations: https://www3.gobiernodecanarias.org/medusa/ecoescuela/recursosdigitales/2015/03/15/activation-energy/ http://recursostic.educacion.es/newton/web/materiales_didacticos/cinetica_quimica/index.html Interactive chart http://www.educaplus.org/game/variacion-de-la-entalpia Simulations: https://phet.colorado.edu/es/simulations/filter https://phet.colorado.edu/es/simulations/reactions-and-rates https://teachchemistry.org/classroom-resources/reaction-rates-simulation
Optical system light collection	Diameter of a bucket of water	Simulations https://www.stelvision.com/astro/en/telescope-simulator https://astronomy.tools/calculators/field_of_view/
Chemical bonding	Affective relationships	Video: https://www.youtube.com/watch?v=FJu9WkFyiaQ&ab_channel=CpechCanalOficial Simulation: (https://phet.colorado.edu/sims/html/molecule-polarity/latest/molecule-polarity_es.html)

Table 4. Summary of analogies and ICT resources proposed in the students' final projects.

2.4.3. Session 3

The session began with the presentation of the final projects completed by the different groups. Following these presentations, each project was analyzed jointly by the educators and the class group, in order to determine their suitability and possible changes or improvements to be made. Next, the final questionnaire was filled out, involving a repetition of the initial questionnaire, with the addition of questions on the evaluation of the intervention performed. Lastly, a discussion was held on the students' perceptions of the training proposal and the contents taught, for which some of the results obtained in the final questionnaire were used as a dynamic element of the session.

2.5. Tools for Gathering Information

2.5.1. Initial and Final Questionnaires

As a tool for gathering information and assess the training proposal, two questionnaires with varied questions were prepared (Table 5), which included items related to different topics: sociodemographic, previous knowledge about analogies, ways to express analogies and types of analogies, notions about appropriate use and application of analogies in the classroom, comparison of analogies with other educational strategies, identification of analogies as an educational strategy used by the teacher, usefulness and difficulties of analogies, assessment of the training proposal.

Dimensions	Initial questionnaire	Final questionnaire
Sociodemographic	2	-
Previous ideas and conceptions	4 (short answer questions)	4 (short answer question)
Concepts, opinions and uses of analogies	29 (21 Likert-type questions scored from 1 to 5, with 1 being the least valued and 5 the most valued / 4 dichotomous yes or no questions / 8 short answer questions)	29 (21 Likert-type questions scored from 1 to 5, with 1 being the least valued and 5 the most valued / 4 dichotomous yes or no questions / 8 short answer questions)
Assessment of the training proposal	-	14 (13 Likert-type questions scored from 1 to 5, with 1 being the least rated and 5 the most rated / 1 short answer questions)
Items total	35	47

Table 5. Structure of the questionnaires

Final project:

1. Detailed description of an analogy of their choice. Analog and topic should be analyzed, as well as the relationships between them and any possible limitations or difficulties. They should also propose digital resources useful for the understanding of the analogy.
2. Design of a didactic proposal of 1-2 sessions intended for secondary education students, where the analogy described is introduced using the proposed digital resources.

2.6. Data Analysis

The data obtained from the questionnaires were analyzed using the *Statistical Package for the Social Sciences* software (SPSS, version 25).

For the analysis of the final projects, a rating rubric was used based on the level of achievement of the different dimensions to be assessed in the final projects. Table 6 shows these categories.

Dimensions	Level of achievement	
D1. Theoretical formulation of A/T	3	Accurate and sufficiently detailed
	2	Accurate, but with no or very generic details
	1	Not accurate
D2. Design planning	3	A consistent design is proposed, with details for its implementation
	2	A design is proposed with a certain consistency, but with a very generic formulation and without details
	1	Not a consistent design
D3. Level of teaching direction in task planning	3	Directed consistently with planning
	2	Not specified or freely indicated
	1	Not consistent with planning
D4. ICT resources	3	Relevant to the improvement of A/T comprehension as a whole
	2	Relevant to the improvement of A/T comprehension in a partial way
	1	Irrelevant to the improvement of A/T comprehension
D5. Design of resources	3	Designed by teachers
	2	Mixed (external and designed)
	1	External (software, internet, etc.)

Note: Each level of achievement is given a value from 1 to 3, with 3 being the best rated and 1 the worst

Table 6. Dimensions analyzed in the final projects

3. Results

Considering the amount of data obtained from the questionnaires and the students' productions, those considered most relevant for the resolution of the questions raised as objectives of this work are presented. In order to facilitate their interpretation and analysis, the data will be presented from different perspectives.

3.1. On Conceptions and Beliefs About Analogies

The concept of "analogy" initially yielded poorly elaborated and erroneous definitions. Most statements consisted mainly of a parallelism with "examples", "similes" or "metaphors" (22.6%, 45.2% and 3.2%, respectively). However, other definitions introduced the comparison between elements, but also in a simple way and only a few developed this idea more thoroughly (22.5% and 6.5%, respectively). After the formative sequence, more complex and theoretically acceptable definitions were observed (16 definitions, 51.6%). Even so, some definitions like those indicated above were also obtained: 4 related to examples (12.9%); 7 to similes (22.6%) and 4 simple comparisons (12.9%), which suggests the need to review the training proposal itself and to continue training students on this subject. Table 7 shows some of the students' definitions before and after the training proposal.

Next, in order to determine whether there was a significant change, this variable was transformed into a dichotomous variable, so that definitions based on examples, similes, metaphors or the mention of a simple comparison were considered "erroneous" and more elaborate definitions that at least refer to a comparison of structure or functions between the elements that constitute the analog, and the topic were considered "acceptable". For this purpose, McNemar's Chi-square test was used, considering a significance level (alpha) of 5%; these data are shown in Table 8.

A value of $p = 0.000122$ was obtained, so that, with an error probability of 0.01%, the conception of analogy before and after the training proposal is different, and, according to the specified significance level, a positive change is confirmed. In other words, the training proposal carried out has allowed the participating students to have a more accurate perception of the analogy.

Before	After	Comparison
It is an example given to explain another similar process, in a metaphorical way.	Comparison of structures and/or functions between two domains of knowledge: one familiar and one unfamiliar or partially new	Specific concepts appear (e.g. "domains of knowledge") and the comparison with a metaphor disappears
An example from everyday life that resembles what is being explained theoretically in class.	It is a comparison between two elements (analog and topic), one of which is unfamiliar and is studied by establishing relationships with the other for its comprehension	The need to establish relationships between the analog and the topic is added
It is using a simile in such a way that by explaining that simile the concept in question is explained	An analogy is a didactic resource used to explain complex topics by comparing them with simple analogs, thus conveying new knowledge to students on the basis of objects which are more familiar to them	It emphasizes the complexity of the topic vs the analog and the transfer of knowledge
A comparison between two or more different things	It is a relationship of equivalence between two "things" or topics, one of which is familiar and the other unfamiliar, in an attempt to facilitate the understanding of the second based on its similarities with the first	It specifies that both domains are unfamiliar and emphasizes the complexity of the topic

Note: Definition of analogy: Comparison of structures and/or functions between two domains of knowledge, a familiar one (topic) and an unfamiliar or partially new (analog) (Duit, 1991; Raviolo, 2009).

Table 7. Conception of analogy

Regarding the usefulness of having knowledge about analogies for teaching, students report high rating values (Table 9). Thus, considering that a scale of 1 to 5 has been used, the mean (hereinafter, M) of the results of the items related to this dimension is M=3.7 before the proposal and M=4.1 after the proposal. This indicates that students have improved their perception of usefulness.

	After					
	Erroneous		Acceptable		Total	
Before	N	%	N	%	N	%
Erroneous	15	48.4	14	45.2	29	93.5
Acceptable	0	0.0	2	6.5	2	6.5
Total	15	48.4	16	51.6	31	100
$X^2(N=31) = 14$, $p = .000122$						

Table 8. Definitions of analogy before and after

Questions	Before (M)	After (M)
Do you think it is necessary to be trained in analogies?	3.3	3.9
To know historical cases of analogies and key analogical reasoning in the construction of science	3.5	3.9
To know the mechanisms of learning by analogies	3.9	4.2
To understand the processual nature of analogical thinking	3.7	4.0
To value the activity of students in the construction of analogies and the regulatory role of teachers.	3.9	4.2
To possess a wide and varied repertoire of contrasted analogies	3.8	4.1
What degree of importance or relevance in general do you assign to analogies for science teaching?	3.8	4.2
Total	3.7	4.1

Table 9. Usefulness of analogies for teaching

Likewise, the perceived usefulness of the combined use of analogies with digital resources has also been rated very positively. Table 10 shows that students consider that the combined strategy can be very useful for teaching.

Questions	M
How useful is the combined use of analogies and digital resources in general?	4.4
What is the overall usefulness of using analogies and infographics together?	4.3
What is the overall usefulness of using analogies and AR together?	4.4

Table 10. Usefulness of the combined use of analogies and digital resources

On the other hand, the main difficulties that students initially pointed out in the use of analogies are the "*selection of analogies that are appropriate to what is to be taught*" and "*knowing how to use analogies in class*", while after the formative sequence, they also mentioned "*understanding and analyzing the analogy further, including its limitations*", which is not easy for them, so they also pointed out that "*more training and time is required for the preparation of the classes*". Another difficulty that was also reported by several students and which is important to note because it introduces the students' perspective is "*the students' perception of the analogy and whether it can generate conceptual errors or distractions from what initially could be considered as fundamental*".

Regarding the combined use of analogies, infographics, and AR, they mainly highlight the "*distractions of students by the use of technology*" since students may focus more o on what is new and impressive than on the content to be explained. They also indicated that it is difficult "*to have or design the appropriate resources*" and, lastly, most of them pointed out "*the teachers' poor digital teaching competence*".

3.2. Integration of Digital Resources in Classroom Designs

The analysis of the final projects shows that only 4 groups planned a design with a high level of adequacy, with a suitable level of adequacy and 2 with a poor level of adequacy (Table 11).

In general, the theoretical formulation of the analogy and the topic was well developed, except for one group. Design planning was relatively consistent, although with little detail. Similarly, the level of teaching direction in task planning was not sufficiently specified (7 groups) and only 4 were consistently directed. Most of the proposed resources were relevant for the improvement of the analog/topic comprehension. Finally, resources from the Internet prevailed and, to a lesser extent, the combination of these with some designs of their own.

Dimensions	**Level of achievement**		**Groups (n=12)**
D1. Theoretical formulation of A/T	3	Accurate and sufficiently detailed	7
	2	Accurate, but with no or very generic details	4
	1	Not accurate	1
D2. Design planning	3	A consistent design is proposed, with details for its implementation	4
	2	A design is proposed with a certain consistency, but with a very generic formulation and without details	7
	1	Not a consistent design	1
D3. Level of teaching direction in task planning	3	Directed consistently with planning	4
	2	Not specified or freely indicated	7
	1	Not consistent with planning	1
D4. ICT resources	3	Relevant to the improvement of A/T comprehension as a whole	4
	2	Relevant to the improvement of A/T comprehension in a partial way	6
	1	Irrelevant to the improvement of A/T comprehension	2
D5. Design of resources	3	Designed by teachers	0
	2	Mixed (external and designed)	5
	1	External (software, internet, etc.)	7
Overall adequacy level	3	Highly adequate (majority of items scored 3)	4
	2	Suitably adequate (majority of items scored 2)	6
	1	Poorly adequate (majority of items scored 1)	2

Table 11. Analysis of the designs made by students

3.3. Assessment of the Formative Proposal

Table 12 shows the assessments of the resources used and the methodology employed by the educators and the overall assessment of the didactic sequence.

It is worth noting that almost all the participants (30) rated very positively the resources used during the class sessions, and more specifically, the examples of analogies proposed, and the AR applications and infographics shown.

As for the methodology used by the educators, they also described it as “Very good” or “Excellent” (29). Only two students rated it as “Optimal”, justifying their choice by stating that some of the activities required excessive technical knowledge.

The results of the overall assessment indicate that the proposal developed has been very well received by the students, since most of them rated it as “Very good” or “Excellent”.

Rating	Resources			Methodology	Training proposal in general
	Resources used	Analogies	ICT resources		
	f	f	f	f	f
Very bad	0	0	0	0	0
Bad	0	0	0	0	0
Very good	1	1	1	2	0
Very good	16	15	15	14	15
Excellent	14	15	15	15	16
Total	31				

Table 12. Assessments by the students

To conclude, some students pointed out several aspects to be considered for future editions. In this sense, they pointed out that they wished they had had more time to expand on what they had learned and felt they needed more training, both in the use of analogies for teaching, as well as in the development of their digital teaching competence.

4. Conclusions

From the analysis of the results obtained, the following conclusions can be drawn:

- The formative sequence favored the positive evolution of the perceptions of prospective teachers about analogies since it improved their conception and the degree of usefulness in science teaching attributed to them.

- The main difficulties identified were related to the availability of a varied set of analogies, the in-depth knowledge of said analogies and their limitations, the preparation time for their use in class and the possible emergence of conceptual errors among students. As for the digital resources, possible distractions and the poor digital teaching competence stand out.

  This is in line with Oliva et al. (2001) when they found that some teachers' ideas about analogies are sensitive to evolution through a training course, while others are not. Similarly, the difficulties mentioned also coincide with that indicated by Oliva (2008) and Oliva et al. (2001) regarding analogies, by Falcó (2017) regarding the poor digital teaching competence and by Mellado and Rivas (2015) regarding the perception of risk in the use of ICT.

- The combined use of analogies and digital resources is valued very positively and considered useful and important for science teaching.

- Other authors (Aragón-Méndez & Oliva, 2020) have found progress in the training of secondary education students through the combined use of analogies and digital resources, so it is encouraging that prospective teachers, following the training proposal experienced, have also expressed their importance in this study.

- The classroom designs presented are consistent, with a more or less accurate theoretical formulation and relevant resources. However, shortcomings were also noted in terms of planning and the scarcity of details of their implementation.

  These shortcomings correspond with the findings of Golías, García and Rivadulla-López (2022) and Toma, Greca and Meneses (2017), who emphasize that there is a need for educators to analyze the productions that prospective teachers are asked to produce and their preparation for doing so. Thus, we agree with Buitrago and Wamba (2009) when they point out the importance of continuing to assess the intervention design, as well as training prospective teachers to address common teaching problems in a reflective, comprehensive, and innovative way.

Finally, even with some of the limitations of this work, especially those referred to the number of participating students and the limited context in which it has been developed, the subject of analogies in science teaching and the results obtained are sufficiently interesting to be taken into account in the initial training of teachers at all educational levels. It is intended, however, as a future possibility, to increase the number of participants and to extrapolate the research to other national and international areas, so as to allow a certain generalization of the results.

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