Chapter 2: Preservice Science Teachers' Demonstration of Critical Thinking Dimensions in Addressing the Socio-scientific Issue of Implementing an Artificial Moon for Street Illumination

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2.1 Introduction

Developing critical thinking (hereinafter, CT) skills in students is currently a priority objective of general education and science education (Osborne, 2014). CT is part of non-university and university curricula and teacher training and is promoted by various international organisations. Despite its importance, the development of CT is a challenge for teachers in science education because, among other aspects, there has yet to be a widely accepted model on how to deal with it successfully in the classroom for several reasons. The first is that CT is a complex construct involving cognitive factors, skills, and dispositions (attitude/motivation) (Vieira & Tenreiro, 2016). Another obstacle is that there needs to be more consensus in science education on the dimensions that comprise it. Furthermore, the nature of the context in which CT is intended to be developed plays an important role in promoting some dimensions or others (Franco-Mariscal et al., 2025). However, despite all these limitations, there is agreement on the importance of promoting CT for action, both from the curricular framework and educational research (Puig & Jiménez-Aleixandre, 2022). As highlighted in Chap. 1 (Franco-Mariscal et al., 2025), recent literature has shown different theoretical approaches for the development of CT in science education (Blanco-López et al., 2017; Solbes & Torres, 2012; Vázquez & Manassero, 2020) around the use of socio-scientific issues (Ariza et al., 2024; Cebrián-Robles et al., 2021a, 2021b; Evagorou et al., 2012). Although these developments are necessary, it is important to have these theoretical approaches and examples of experiences that show science teachers their designs and how to adapt these integrated approaches to CT to the reality of the classroom, as they are not yet widespread. Analysing these experiences will help teachers identify the dimensions of CT in the activities they propose, integrate them, and provide them with references for new designs. The choice of the problem to be addressed is also important. Energy is a case in point as a key concept in science curricula (Park & Liu, 2016). Its teaching is still primarily conceptual, although it is increasingly necessary to address it as a socio-scientific issue given that it is a complex and global challenge that requires mechanisms of action, which must be carried out both globally and individually (DeBoer, 2011; Martín-Gámez & Erduran, 2018). Therefore, this chapter proposes a design for integrating CT into socio-scientific issues and analysing its potential. This aspect needs to be explored in science education, as exemplified in a current case related to energy use.

2.2 Critical Thinking Development Through the Socio-Scientific Issue of Implementing an Artificial Moon to Illuminate a City

The use of energy in its different aspects (consumption, production, transport, use, alternative energy sources, etc.) constitutes a socio-scientific issue due, among other aspects, to greenhouse gas emissions as the gases responsible for climate change. Like any socio-scientific issue, it is a real and complex problem that affects all spheres (personal, local and global) because scientific-technological, economic, social, environmental, ethical, etc. aspects converge (Martín-Gámez & Erduran, 2018). In turn, these issues are controversial and raise debate in society and the media (Díaz & Jiménez-Liso, 2016) about the convenience or not of their use or implementation for different reasons (safety, environmental impact, economic cost, etc.). The position adopted by each citizen will also depend on several factors: their scientific knowledge of the issue, the critical analysis they make of the information they receive or seek from different sources, the possibility they have to confront their ideas with other people and argue their own, etc., all of which are important dimensions in the development of CT in citizens (Blanco-López et al., 2017). In the current context, the issues surrounding the use of nuclear energy have once again been placed high on the political agenda and in the media as it seeks to be labelled as green energy in the process of ecological transition (United Nations, 2015). Along these lines, the 2030 Agenda considers climate change as one of the most significant challenges facing the international community (United Nations, 2015) and includes a Sustainable Development Goal (SDG13, Climate Action) designed explicitly for this purpose. This goal calls for urgent action involving all citizens to combat climate change and its effects. Some countries, like China, are already promoting measures such as implementing an artificial moon with a coating to reflect sunlight to illuminate cities at night (SpaceChina.com, 2018). The problem, which appeared in different media, consisted of replacing the current lighting system in a town with an artificial satellite (called an artificial moon) built with solar panels, which would allow, according to the company responsible for the project, to illuminate a city at night with considerable energy savings. Next, we examine the contributions that the ENCIC-CT model (Chap. 1) can make to developing CT, delving into the dimensions that citizens need to activate to address this issue and make decisions about it. To face this problem, the first dimension to develop is the critical analysis of information. In this case, data from environmental, social, economic, technological, energy, ethical, etc. perspectives on the impact of its construction and use would be necessary. Among the environmental factors to be considered are whether it is an environmentally friendly alternative for using solar energy as renewable energy and what impact it will have on the ecosystems of the area, especially on the behaviour of the flora and fauna as it receives light 24 h a day, and light pollution, among others.

Personal factors to consider include how constant light at night affects people's sleep cycle or their rhythm of life and the daily activities organised around day and night. From a social point of view, one could analyse how it would affect work, trade, and cultural activities, as well as the possibility of the artificial moon becoming a new tourist attraction that would affect the economy. As economic factors, it would have to be considered whether removing the lighting would save the city electricity or how long it would take to amortise the cost of construction, installation, and

maintenance. The technological/energy aspects to be assessed would be related to the feasibility of the project being carried out successfully, the energy needed to supply the moon with light, and the control that this light only illuminates the city. Finally, at the scientific/technological level, the possibility of closing down existing astronomical observatories in the area should be considered, among other consequences. Considering all these factors together would also involve assessing whether it would be ethical to implement a moon that could bring about abrupt changes in how people live. With all this information in hand, critically analysed, citizens would be better able to make more informed and responsible decisions. In reality, the analysis of such a volume of information is not usually common, as it would require a great deal of time and effort for the citizen and, in turn, because the information available in the media and social networks usually appears as one-off news items and from very few perspectives, which can sometimes even correspond to fake news (Puig et al., 2021). In this way, the decision may lead us to a position different from the one the citizens would have if they had a more complete view of the issue. It is, therefore, essential to promote this critical analysis of information at school (Blanco-López et al., 2015) to help students improve and develop their informal reasoning, which is used in the field of socio-scientific issues (Sadler & Zeidler, 2005).

On the other hand, citizens generally do not approach these issues and their analysis individually but interact with different people close to them in their family, personal sphere, etc., so that the decision-making above. However, it can be understood as personal and is very much conditioned by the social environment (Zeidler, 1997). Bearing that social interaction is very important, CT also requires the development of personal autonomy because they do not allow themselves to be uncritically dragged along by currents of thought or predominant positions on a given problem.

Another important dimension for tackling problems such as the one discussed here is scientific argumentation, which is fundamentally based on evidence (Erduran & Jiménez-Aleixandre, 2008). In this case, as the artificial moon has not yet been implemented, the necessary data are unavailable to assess the positive and negative aspects. Therefore, citizens will have to base their arguments on the scientific-technical reports available on the possible impacts or the arguments provided by scientists and people with a solid background in this field.

Nowadays, citizens' involvement in such issues also entails participation in various discussion forums, such as social networks, associations, and activist projects. CT demands that these citizens communicate their decisions using appropriate language according to the context and goals or intentions.

Likewise, the development of CT requires the application of scientific knowledge to the issues addressed. In this example, the knowledge involved is the concept and use of renewable energies, their use, the environmental impacts of their construction, use and maintenance, the technological aspects related to implementing the moon as a geostationary satellite, etc.

2.3 Research Questions

This chapter poses the following research questions (RQ):

- RQ1: Which CT dimensions are displayed by preservice science teachers in an experience addressing the socio-scientific issue of implementing an artificial moon to illuminate city streets?
- RQ2: In what ways can the development of these dimensions of CT be encouraged when presenting information about the problem through a headline or more detailed readings?

The hypothesis for RQ1 suggests that, although the experience focuses primarily on critical analysis of information, argumentation, and decision-making about the socio-scientific issue addressed, it also facilitates the development of other dimensions of CT in preservice teachers. As for the hypothesis in RQ2, it is expected that the development of these dimensions will become more conducive as more information is provided to preservice teachers.

2.4 Method

2.4.1 Participants and Context

This experience is part of a broader programme focused on developing CT dimensions in Spanish preservice teachers (Hierrezuelo-Osorio et al., 2022) based on different socio-scientific dilemmas such as sugar consumption, the use of autonomous cars, the suitability of a vegan diet, the banning of single-use plastics, or the implantation of an artificial moon. This program was implemented with 80 preservice teachers, specifically in the Degree in Primary Education (N = 45) and two specialisations (Physics and Chemistry, and Biology and Geology) of the Master's Degree in Teaching of Secondary Education (N = 35) at the University of Malaga (Spain). For the preservice primary teachers, the average age was 21 years, with 88.8% female and 22.2% male, while for the preservice secondary teachers, the average age was 28 years, with 57.1% female and 42.9% male.

2.4.2 Experience Description

The experience associated with the issue of implanting an artificial moon was organised in the following sequence of tasks:

- *Instruction in argumentation.* The teacher conducted a training session explaining how different authors understand argumentation, emphasising its importance in everyday life, science education, and its contribution to CT. Toulmin's (1958) model of argumentation and Osborne et al.'s (2016) model were shown. The first step was to identify the essential elements of an argument (evidence, warrant and conclusion) through a simple example where they observe the tracks of an animal in the snow as evidence to give an argued answer to the question, *who is walking in the snow?* (Cebrián-Robles et al., 2021a). As a second step, it was proposed to argue whether a young redhead with white skin and freckles whose image was shown was likely to get sunburnt (Cebrián-Robles et al., 2021a). They aimed to recognise the importance of refuting arguments and learning about scientific preconceptions. Different dimensions of CT were also presented, focusing on the ENCIC-CT model (Franco-Mariscal et al., 2025).

- *Task 1*. Preservice teachers must make an initial reasoned decision about the issue by showing their agreement or disagreement with the headline: *A Chinese city is building its own "artificial moon" to illuminate its streets* without the possibility of accessing any information. In addition, this headline was provided online, and the preservice teachers had to formulate three arguments for and three against, including the corresponding warrants.
- *Task 2*. Preservice teachers are provided with the same headline accompanied by two adapted readings that present opposing arguments (one for and one against) (Revista Digital El Debate, 2018; Romero, 2018) so that they can identify them and, if they think it is appropriate, use them to develop new written arguments on the issue. The texts contain different evidence and warrants around four key aspects for understanding the issue regarding socio-economic, technological, energy-saving and environmental impacts. For its design, a search and analysis of information from different sources was carried out to ensure that the readings included arguments for and against the issue.
- *Task 3*. Preservice teachers must return to a final decision by reasoning based on a critical analysis of the information presented in the readings. Preservice teachers were required to identify arguments for and against the issue in the readings and use them to make a final reasoned decision.
- *Task 4*. An oral discussion is held in the classroom to find out about the different positions adopted.

2.4.3 ENCIC-CT Model Application

This experience employs the ENCIC-CT model (Franco-Mariscal et al., 2025) to examine the energy issue through the potential implementation of an artificial moon to illuminate a city (Layer 1). This socio-scientific issue is particularly relevant as it spans several domains, including technological, social, economic, energy, and environmental aspects, among others. The activity is designed to develop a critical analysis of information, argumentation and decision-making dimensions within the skills domain (Layer 2). Nevertheless, it also has the potential to advance other dimensions of the ENCIC-CT model across the knowledge, skills, and disposition domains, as explored in research question RQ1. The scientific practice of argumentation (Layer 3) addresses and critically analyses the issue. Finally, media sources (Layer 4) are integrated into the teaching strategy, specifically through two reading press articles, providing a contextual foundation that enriches understanding, enhances knowledge application, and supports well-informed decision-making.

2.4.4 Data Collection and Analysis

The data collection instrument was the preservice teachers' written productions, which were generated as responses to tasks 1 and 3 described in the experience description. These written responses were systematically collected using Google Forms, ensuring that all preservice teachers' responses were stored consistently, facilitating easier analysis and review.

The productions were subjected to a rigorous qualitative analysis to identify evidence aligned with the ENCIC-CT model's dimensions. To ensure a comprehensive analysis, a collaborative and iterative approach was employed. This involved several rounds of analysis, during which the authors worked together to refine and develop analysis units. These units served as the foundational elements for identifying and categorising the various dimensions of CT present in the participants' productions. Table 2.1 presents the analysis units used. For each participant, the frequency of each unit of analysis in each task, and whether it referenced each domain of CT (knowledge, skills, and dispositions), was calculated. Additionally, the percentage of preservice teachers in each group (primary or secondary preservice teachers) that referenced each dimension was determined.

Two analyses were conducted for each group of preservice teachers between the initial and final tasks. First, the McNemar test was used to identify statistically significant differences in each dimension of CT, as it involved related samples and dichotomous nominal variables. Second, the Wilcoxon test was applied to determine significant differences in the number of CT domains referenced in the tasks, given that the study dealt with related samples and ordinal variables.

Two statistical tests were used to analyze possible differences between the two groups of preservice teachers. The chi-square test was employed to identify significant differences in each dimension of CT in both the initial and final tasks, given that the samples were independent and the variables were nominal. Additionally, the Mann–Whitney U test was used to assess possible differences in the number of CT dimensions referenced and the number of domains, considering that the samples were independent and the variables were ordinal.

Table 2.1 Units of analysis related to the ENCIC-CT model

Domains	Dimensions	Analysis units
Knowledge	Knowledge application	KA
	Vision of science/epistemic knowledge about science	VS
Skills	Comprehensive analysis of the problem	CAP
	Critical analysis of information	CAI
	Argumentation	A
	Decision-making	DM
	Communicative skills	CS
Dispositions	Personal autonomy/metacognition/reflection	PA
	Social engagement/activism	SE
	Emotional engagement	EE

2.5 Results

2.5.1 Results for Research Question 1

This section presents evidence found in the productions of preservice teachers regarding the development of the dimensions of CT proposed by the ENCIC-CT model, illustrating them with several examples in the different domains:

- Knowledge Domain

  – *Scientific Knowledge Application and Knowledge About Science* (KA).

  Through the readings, the activity provides the scientific knowledge involved in the socio-scientific issue (renewable energies, environmental impact, satellite deployment, etc.) that the participants must understand and apply to their arguments.

  > I am against introducing the artificial moon because it can have a considerable environmental impact. On the one hand, it modifies the photoperiod of plant organisms, which can cause an imbalance in the ecosystem. It can also negatively impact animal organisms, as many have nocturnal cycles, and humans, whose circadian cycles can be influenced and affect the production of certain hormones, such as those that encourage sleep when there is no light (Preservice secondary teacher 20).

  – *Vision of Science/Epistemic Knowledge About Science* (VS).

  This dimension is present in the issue. First, the headline of the activity and, subsequently, the information provided by the two readings should make preservice teachers reflect on the role of scientific research in implementing the artificial moon and its direct impact on environmental and socio-economic aspects.

  > Based on the information provided, I would not pursue the project. I am not saying it could not be carried out at some point. Still, first, I would insist on continuing the research and see if the moon would negatively affect certain aspects, such as fauna and flora or intense light pollution (Preservice secondary teacher 14).

  This participant applies to the analysis of this issue the need to obtain solid evidence as a characteristic feature of scientific research before considering the construction of the artificial moon.

- Skills Domain

  – *Comprehensive Analysis of the Problem* (CAP).

  The readings provide the necessary information to understand the issue from all perspectives (scientific-technological, environmental, social, economic, etc.), which should help preservice teachers form their arguments. Information is provided from opposing positions to make them reflect on different solutions.

  > My position favours the artificial moon, as it could significantly reduce light pollution and non-renewable energies to invest in other renewable energies. However, in defending this, I have not considered all the living beings that could be affected, remain awake, and carry out their evolutionary process and reproduction at night. I do not consider this a problem for human beings since darkness can be achieved in many ways without the need for darkness outside, but for living beings whose habits depend on the outside world and the cycle of the day, it is a problem. Therefore, it is necessary to read much more about it to know the advantages and disadvantages of this issue and to conclude with a personal point of view subject to valid arguments (Preservice primary teacher 42).

  In its response, this preservice teacher reasonably comprehensively analyses the problem by including several perspectives (environmental, social, and scientific-technological) and recognising the need for more information to obtain a complete picture of the issue.

  – *Critical Analysis of Information* (CAI).

  The readings' content allows them to assess the credibility of the

information provided, as they include data backed up by reliable sources, such as astrophysicist Dr. Sánchez of the University of Exeter (see Annex). Also, in situations of uncertainty, preservice teachers can turn to other sources to explore the topic further.

> Firstly, accepting the widely held view that implementing an artificial moon would not cause serious environmental damage is counterproductive. The ecological impacts are severe and palpable. Secondly, the nocturnal activity of some living beings would be altered. Animal species and ourselves would be affected, so the "positive" consequences alluded to in the texts are refuted, in my opinion.
>
> Before concluding, I would like to allude to the argument about the economic savings benefits mentioned in both news items. For me, the background could be called "social-political opportunism". The second text comments on the tourist attraction that the implantation of an artificial moon would bring about. It is somewhat ironic how they make us see that, on the one hand, it is suitable for the population (because the government saves capital that it invests in public lighting), but on the other hand, they present us with the counterpoint that it benefits tourism and, therefore, the country's economy. In short, my position is contradictory since, in general terms, introducing the artificial moon in China goes against the natural and biological process of developing the species. (Preservice primary teacher 10).

– *Argumentation* (A).

It is proposed as a key dimension integrated into all the tasks set for different purposes and in two formats (written and oral). Thus, in the initial and final decision-making tasks, preservice teachers must provide written arguments supported by evidence. In the first case, based on evidence or personal experiences related to the possible impacts that the implantation of the artificial moon could produce, and, in the final decision, based on possible arguments offered in the readings. Similarly, the readings themselves, where it is not made explicit whether one is for or against, should enable participants to identify different arguments and their elements (evidence, warrant, and conclusion) and the quality they present within them. The aim is for them to be able to create solid arguments once they have a broad view of the problem. The final pooling allows them to develop oral arguments and counter-arguments and to discuss them in the classroom.

> The arguments favour using this artificial moon could be stronger than the significant disadvantages it produces. The lives of human beings and many animals and plants would be seriously affected, which are fundamental to any ecosystem. These facts are hidden in the second news item, which includes arguments such as an increase in the city's economy, tourism, or energy savings. We could agree on the latter measure of saving energy and reducing the pollution generated by coal production. However, these factors cannot be compared with the repercussions and consequences for nature and, above all, for living beings, as this is even more important than the economy or tourism of a city. It would even impact astronomical research, which could find a more viable solution to create another satellite that is not so harmful to the ecosystem (Preservice primary teacher 09).

This answer shows a high level of argumentation by recognising the arguments supporting both positions (for and against the construction of the artificial moon) and counter-arguing those who take a proposition.

– *Decision-Making* (DM).

This dimension takes place at two points: at the beginning and the end of the experience. Only the individual's ideas intervene in the initial decision,

while the arguments may influence the final decision in the activity. The aim is for the preservice teacher to rely on the arguments given or on their arguments to support their initial decision or to change their position on the problem after learning about other arguments.

> I am against artificial moon implantation. However, despite the many benefits it may have, the negative impact is more significant. Moreover, other countries could take this initiative as a reference and implement these artificial systems, which would increase the negative impact (difficulty in visualising the stars, alteration of ecosystems, alteration of citizens' circadian cycles, etc.) (Preservice secondary teacher 23).

– *Communicative skills* (CS).

Although the experience focuses mainly on written communication, it also provides opportunities for oral communication. Thus, the sharing aims to encourage dialogue in the classroom so that preservice teachers can present their decisions using appropriate scientific language and, later, be able to do so in other contexts, using scientifically based arguments.

- Dispositions Domain

– *Personal Autonomy/Metacognition/Reflection* (PA).

The proposed tasks are intended to enable preservice teachers to develop independent opinions and reflect on them. It is also important for them to assess whether they already have enough information to decide or reflect on their degree of certainty.

> This is a complicated answer. Considering its effects on the environment, light pollution and possible effects on humans, no. However, there are other aspects to consider, such as the research and innovation needed to carry it out and the information we can obtain from this experience. However, there are different aspects to consider, such as the research and innovation required to carry it out and the information we can obtain from this experience, so I would favour implementation to advance technologically (Preservice secondary teacher 10).

Some preservice teachers do this autonomously by seeking additional information. However, to promote this dimension for all participants, they can be asked to seek further information on the problem that has had the most significant impact on them.

– *Social Engagement/Activism* (SE) *and Emotional Engagement* (EE). These two dimensions of CT were not found in the analysis.

2.5.2 Results for Research Question 2

The analysis of the development of these dimensions about the amount of information provided to the preservice teachers revealed more concise reasoning in cases where only the headline was provided (task 1). In most cases, these reasonings focused on the information provided, as can be seen in the responses of the same participant for both moments:

> Using an artificial moon would decrease the expenditure of street lamps worldwide, as the planet would always be illuminated. (Preservice primary teacher 16, production from information provided by the newspaper headline in task 1).
>
> I am in favour of implementation because, firstly, through this initiative, we would be more

> environmentally friendly and a large part of the energy expenditure would be saved, as the satellite would act as an artificial moon and provide light for the city. Secondly, the light from the satellite would be carefully controlled so that it would only illuminate from 10 to 80 kilometres above the ground. In this way, the satellite would not illuminate outside this city. Finally, its deployment would increase tourism by becoming an attraction that would bring people from all over the world. (Preservice primary teacher 16, production from information provided by the readings in task 3).

Table 2.2 shows the findings of the analysis of the preservice teachers' productions, focusing on the different units of analysis. Regarding each group of preservice teachers, the McNemar and Wilcoxon tests did not find statistically significant differences in preservice secondary teachers, but they did in preservice primary teachers. The McNemar test revealed statistically significant differences in the critical analysis of information (CAI) dimension ($p = 0.016$), favoring the task where the preservice primary teachers group accessed information about the problem. Similarly, the Wilcoxon test identified differences in the skills domain ($Z = — 3.138$; $p = 0.002$), favoring this same task and group of preservice teachers. The chi-square test indicated that the two groups were homogeneous, as no statistically significant differences were found between them in the initial task. However, after accessing the information, this test identified significant differences in preservice primary teachers, particularly in the knowledge application (KA) ($x2 = 8.889$; $p = 0.003$) and critical analysis of information (CAI) ($x2 = 4.007$; $p = 0.045$) dimensions. Furthermore, following the activity, the Mann–Whitney U test showed differences in both the knowledge ($U = 634.00$, $p = 0.013$) domain and the total domains ($U = 635.00$, $p = 0.013$), both favoring the preservice primary teacher's group.

Table 2.2 Percentages of the units of analysis for both groups of preservice teachers

	CT domains	Knowledge		Skills					Dispositions		
	CT dimensions	KA	VS	CAP	CAI	A	DM	CS	PA	SE	EE
Preservice primary teacher	Initial (Task 1)	8.9	4.4	22.2	84.4	53.3	77.8	0.0	2.3	0.0	0.0
	Final (Task 3)	22.2	4.4	33.3	100.0	73.3	88.9	0.0	0.0	0.0	0.0
Preservice secondary teacher	Initial (Task 1)	8.6	2.9	20.0	80.0	40.0	88.6	0.0	0.0	0.0	0.0
	Final (Task 3)	2.9	2.9	22.9	91.4	60.0	94.3	0.0	0.0	0.0	0.0

Note KA Knowledge Application, *VS* Vision of Science, *CAP* Comprehensive Analysis of Problem, *CAI* Critical Analysis of Information, *A* Argumentation, *DM* Decision-making, *CS* Communicative Skills, *PA* Personal Autonomy, *SE* Social Engagement, *EE* Emotional Engagement

2.6 Discussion and Educational Implications

This chapter has highlighted the importance of classroom experiences and practical examples that immerse preservice teachers in practice and foster CT development. Emphasis has also been placed on the approach to socio-scientific issues, as they can

play different roles in developing various dimensions of CT and on the need to link them to a specific approach capable of integrating them, in this case, the ENCIC-CT model. The qualitative analysis has shown that addressing the socio-scientific issue of implementing an artificial moon to illuminate city streets can indirectly develop the ENCIC-CT model's CT dimensions, particularly in the knowledge and skills domains (RQ1).

Regarding RQ2, the findings (Table 2.2) indicate an increase in the percentage of preservice primary and secondary teachers in the development of most CT dimensions when they were provided with readings, compared to when they only had access to the news headline. These findings suggest that the experience was effective in enhancing their CT.

Decision-making (DM), critical analysis of information (CAI), and argumentation (A) are the three predominant units of analysis in both the initial and final tasks for both groups. These dimensions align with the expected outcomes of the experience's design. Notably, a significant improvement is observed in critical analysis of information (CAI), wherein 100% of the preservice primary teachers are achieved in the final task. The observed improvements in addressing the issue comprehensively suggest that the readings offered a broader perspective than what was not available from the newspaper headline.

Although the two groups show improvement across most dimensions, preservice secondary teachers begin with higher percentages in decision-making (DM) compared to preservice primary teachers. This could indicate differences in prior experience or specialized training between the groups in this dimension.

Some dimensions, such as vision of science (VS), communicative skills (CS), personal autonomy (PA), social engagement (SE), and emotional engagement (EE), show little or no change in both groups. This indicates that these dimensions were not as relevant to the tasks performed and that, despite their presence, the preservice teachers could not effectively apply them.

It is important to highlight that incorporating additional information significantly enhances the CT dimensions under analysis. Access to more extensive data and knowledge enables a deeper understanding and more effective application of these dimensions. Moreover, this additional information not only strengthens existing skills but also promotes the development of new ones, thereby expanding the range of competences. In essence, providing more information results in a qualitative improvement in the development of CT dimensions.

However, these improvements are only statistically significant for preservice primary teachers, specifically in the critical analysis of information (CAI) dimension and the skills domain, favoring the final task. Additionally, group comparisons reveal that preservice primary teachers perform statistically better than preservice secondary teachers in the final task, particularly in the knowledge application (KA) and critical analysis of information (CAI) dimensions, as well as in the knowledge domain and across the total domains. Since the described activity was the first in the training program for both groups, the observed differences could be attributed to the greater prior familiarity of the preservice primary teacher participants with the analysis of written news, particularly in language-related subjects. We have no evidence that preservice secondary teachers had engaged in similar tasks during their

science degree studies.

Experiences for this purpose should provide teachers with examples of developing CT, which will help them put them into practice and design new ones. Once the experiences have been designed and evaluated, they can be transferred to other teachers (Leach & Scott, 2002). It is essential to present the experience as fully as possible, explaining the ideas underlying their design and their contribution to developing CT (Muñoz-Campos et al., 2020). It is equally important for this analysis to form part of initial and in-service training programmes for science teachers.

One limitation of the experience lies in the selection of items used. Both assume that implementing the artificial moon is technologically possible, but this may be different as it would mean putting it into a geostationary orbit, requiring a considerable moon size to capture enough light and reflect it. To assess whether implementation is possible requires advanced physical and astronomical knowledge that was outside the reach of the preservice teachers, hence the decision to present readings that assumed the project was feasible to argue the pros and cons. However, this fact was not noted by the participants, and if it had happened, it would be further evidence of the degree of development of their CT.

Finally, after analysing and discussing the findings, the authors consider that this type of experience is valid for fostering CT among students at different educational stages, not only in initial teacher training. Moreover, it would be interesting for these future teachers to offer them more opportunities to confront their points of view with those of other people. This can be done by including specific tasks that demand this confrontation beyond identifying arguments for and against the issue. In summary, it would be a matter of providing them with global training, both as learners, through their development of CT using this type of experience, and as teacher trainees, providing them with educational strategies where they can transfer the knowledge acquired to their future educational practice.

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