Teaching and Learning Geology as a Way to Develop Thinking and Encourage Positive Attitudes Towards Science

Carmela García-Marigómez – Universidad de Valladolid 0000-0002-2642-9265
Vanessa Ortega-Quevedo – Universidad Complutense de Madrid 0000-0002-5742-4678
Cristina Gil Puente – Universidad de Valladolid 0000-0001-5794-5564

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Correspondencia a través de **ORCID**: Carmela García-Marigómez **0000-0002-2642-9265**

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Abstract: The need to promote scientific literacy and the development of high-order capacities to provide a quality response to students in keeping with the new society has produced a growing interest in approaches that show contextualised science and in movements that promote learning to think to learn. Therefore, the objective of this project was to design materials and activities with scientific content from the inquiry point to favour these aspects and encourage vocation. The design to unite research and school reality has been mixed using the LeTiS scale and the qualitative analysis of the students' production. The study results showed that the designed activities promoted the beginning development of scientific and thinking skills. In addition, it is considered that the proposal applied through a more lasting intervention can improve positive attitudes towards science. In conclusion, it is highlighted that the didactic resources developed were effective, allowing the improvement of the scientific culture and the creation of a culture of thought.

Keyword: Attitudes Towards Nature of Science and Technology

La enseñanza y aprendizaje de la Geología como vía para desarrollar el pensamiento y las actitudes positivas hacia la ciencia

Resumen: La necesidad de promover la alfabetización científica y el desarrollo de capacidades de orden superior para dar una respuesta de calidad al alumnado acorde a la nueva sociedad ha producido un creciente interés en enfoques que muestren una ciencia contextualizada y en movimientos que promuevan el aprender a pensar para aprender a aprender. Por lo tanto, el objetivo de este proyecto fue diseñar materiales y actividades de contenido científico desde la indagación para favorecer estos aspectos y, además, estimular las vocaciones. El diseño llevado a cabo para conseguir unir investigación y realidad escolar ha sido mixto a través del uso de la escala LeTiS y en análisis cualitativo de las producciones del alumnado. Los resultados del estudio mostraron que las actividades diseñadas promovían el inicio del desarrollo de destrezas científicas y del pensamiento. Además, se considera que la propuesta aplicada a través de una intervención más duradera puede mejorar las actitudes positivas hacia la ciencia. A modo de conclusión, se destaca que los recursos didácticos elaborados fueron eficaces permitiendo la mejora de la cultura científica y la creación de una cultura de pensamiento.

Palabra clave: Actitudes hacia la Naturaleza de la Ciencia y la Tecnología

Introduction

The current reality demands that from an early age, we promote scientific literacy in students that gives meaning to science content, moving away from transmissive methods that only focus on the memorisation of contents and implementing more participatory models that work on the social relevance of science and technology (Acebedo et al., 2003). In addition, the complexity that characterises the current reality requires that we take advantage of the scenes provided by science education to develop higher-order skills such as critical thinking (Scott, 2015). Learning to think to learn is essential to face the complex challenges of information and uncertain society (Ortega-Quevedo et al., 2022).

In this sense, a research process based on an intervention proposal is designed, planned, and implemented. The process focuses specifically on studying the Earth and developing thinking through aspects close to the daily life of students and accessible to their evolutionary stage. The introduction of this subject is driven by the scarce geological culture of citizenship (Ilustre Colegio Oficial de Geólogos, 2018). This deficit has caused consequences that the designed proposal tries to solve, such as the insufficiency of critical capacity about the consequences of human activity on the planet, the ignorance about the usefulness of rocks and minerals, the consequences of their unsustainable use, the lack of knowledge about the value of science and technology for human development... The nature of the research also aims to con-tribute to the advancement of the area by including a diagnosis and an intervention proposal. As reflected in the literature on the nature of science and technology or in the literature on attitudes towards science, studies focusing on diagnosis (Abd-El-Khalick et al., 2015; Guzey et al., 2014) are frequent. Still, interventionist studies (Ortega-Quevedo et al., 2022; Cobo et al., 2022) show the potential and opportunities for science education from an early age are scarce.

Scientific Literacy from an Early Age

In today's society, science (and technology) plays a very important role in the integral development and the active and critical participation of people. It is necessary to act in the face of socio-scientific issues in the public and private spheres, as the world is the product of techno-scientific research (Vázquez & Manassero, 2007).

Science, therefore, is a social and cultural phenomenon that should be part of educational processes from the earliest ages of its value in promoting autonomy, being a further reinforcement in the formation of critical and committed citizens, more so now when Science and Technology (S&T) play a fundamental role in our society (Solbes et al., 2007). Likewise, it can be a reinforcement to deepen intellectual competencies (such as learning to learn and think) essential in the new society. Its adequate transmission can constitute an intellectual adventure that promotes acquiring this culture and its various benefits.

Despite these social characteristics, the scientific-technological literacy of citizens has been repeatedly evaluated as inadequate over the decades (Pleasants et al., 2019), and the decrease in time dedicated to this area in school curricula continues to be perceived (predominantly in the first years of schooling). In addition to this exclusion or low engagement, there are several problems arising from the teaching approach taught in educational processes, such as the negative (unattainable knowledge) and simplistic (poor understanding due to dogmatism and decontextualization with everyday life) view of science, the rejection of training and participation in social science issues. Therefore, there must be a change in the educational processes.

From that perspective, lines of study within science didactics such as the implementation of the Nature of Science and Technology (hereafter NoS&T) highlight the need for scientific literacy not to stop at what science is but to go beyond it by reflecting on science and its role in society (Muñoz-García, 2014). In the present study, the STS Tradition Update (Science, Technology and Society) by Manassero-Mas & Vázquez-Alonso (2017) is taken as a reference because it is considered to offer the best way to incorporate a broad, inclusive (science for all people) and complete NoS&T, as well as in a contextualised manner for possessing aspects related to epistemology, the influence of society on science and technology and vice versa and the internal sociology of science.

We must consider that the introduction of the STS consensus must take place in an integrated manner from the immediate environment and through participatory methodologies through real and motivating challenges for students to transmit an useful and real science.

The Relevance of Geology in the Development of Scientific Culture

Correct scientific literacy must include those disciplines essential to develop the knowledge, skills, and attitudes necessary to participate actively and critically in society.

However, in the Spanish educational curricula, it can be observed how Geology is relegated to the background despite being essential to understand natural phenomena, to understand the relationships between society and nature and to understand how we influence it. Therefore, understanding how the Earth works is an essential objective. The Earth is a dynamic system on which we and the rest of organisms depend. Earth sciences are essential to provide answers to various questions of the 21st century society such as climate change, sea level variations, resource sharing, extinction and emergence of species, earthquakes.... (Pedrinaci et al., 2013).

Attitudes Towards Science: The Union of Reason and Emotion

As mentioned above, science education must confront the negative and simplistic view of science. Transmissive teaching methods have affected not only the presentation and understanding of scientific content but also negatively affected students' attitudes (towards science and science-related attitudes) in this field of knowledge. This causes a decrease in scientific vocations and an increase in the social rate of scientific illiteracy (Vázquez & Manassero, 2007).

However, we cannot claim that the usual science teaching is the only cause. Solbes et al. (2007) include in their study various causes, such as the social valuation of science, gender problems, and the organization of the education system and Vázquez & Manassero (2007) include others, such as the perceived difficulty of this area, lack of interest, boredom, the uselessness of learning... Aspects that influence and are related to factors that act on emotions, attitudes or beliefs such as gender, age, self-concept, motivation, family, school environment... This highlights the erroneous dichotomy produced in the classroom over the years: the separation between reason and emotion.

The study of attitudes in this and other fields is complex. Although research in Science Education has focused on this field, studies focused on students under eight years of age (Paños & Ruiz-Gallardo, 2020; Kerr & Murphy, 2012; West et al., 1997), as well as studies that conceive science as a reality close to the everyday life of students outside school (Brown, 1991; Trundle, 2015) are scarce. In this sense, Paños & Ruiz-Gallardo (2020) propose the development and validation of an instrument to measure the attitude towards informal science (that is linked to informal learning about the natural world derived from children's curiosity such as observing ants, collecting stones...) in students aged five to six years old. Specifically, as explained below in the techniques and instruments used in the research, the instrument includes the attitudinal components focusing on taste and behavioural intention.

Attitudes can be positive or negative and have a learned character that makes them a fundamental factor to consider in the educational field because they influence behaviour and learning (Sarabia, 1992; Martín-Baro, 1983). Moreover, attending to the Theory of Reasoned Action developed by Azjen & Fishbein in 1980 states that to predict behaviour, it is necessary to ask about the intention to perform it (Hogg & Vaughan, 1995; Ubillos et al., 2004). This premise and the objective of promoting scientific vocations led us to select the instrument indicated above.

From this perspective, the STS approach offers opportunities to abandon the abuse of epistemic contents characterised by logical positivism, giving way to an adequate vision of science that includes aspects of both internal and external sociology, recognising and exposing the presence of emotions, habits, values and attitudes in science and technology. Teachers must take advantage of affective variables so that students enjoy and acquire meaningful learning, thus favouring their vocations, scientific literacy, and integral development.

Transversality, Inquiry, and Visible Thinking

As indicated above, the proper introduction of the STS approach is based on the integration and contextualisation of knowledge, as well as on the use of active methodologies that allow leaving behind the passive action of students.

In this sense, on the one hand, an explicit transversality (Magenzo, n.d.) is introduced in the proposal that enriches and brings disciplines closer together and allows students to prepare themselves for life by understanding the complexity of today's world to act from different fields of knowledge, transferring their learning. Specifically, aspects of Geology were introduced from environmental problems and issues related to social and civic values, citizenship, and democracy. On the other hand, the proposal designed is framed at a pedagogical level in the constructivist model to paying attention to these alternative conceptions since they can constitute an obstacle to learning (Garrido et al., 2007).

As for the intervention, this is governed principally by the Inquiry Methodology, that allows students to learn science early to make sense of the world around them (Uzcátegui & Betancourt, 2013). Inquiry-based science allows the development of both skills and correct scientific literacy. To develop the didactic proposal, Model-Based Inquiry (Figure 1) is included. Following the ideas of Hijonosa & Sanmartí (2016), inquiry aims to use, evaluate, readjust, and create models to explain reality.

Figure 1. Elements of the inquiry methodology.

This methodology is integrated with visible thinking (Ritchhart et al., 2014) to promote deep thinking and learning that favours the acquisition of higher-order capabilities. Visible thinking is a conceptual framework whose objective is to integrate the development of thinking moves (like making connections, reasoning with evidence, wondering and asking questions, etc.) with different curricular learning at any educational stage (García-Martín & Gil, 2020). This approach allows us to overcome models based on transmission-reception, giving way to models centered on the student and his or her development since visible thinking promotes students to acquire greater mastery of mental processes by externalizing them and facilitates understanding by working from an observable perspective. In addition, this visualization process favours the teacher to discover what and how students learn (Ritchhart et al., 2014). Bringing their thinking to light offers evidence of their ideas and alternative conceptions, revealing the underlying aspects of the error and allowing us to provide them with feedback tailored to their needs (Brooks et al., 2019). It is a key tool to carry out a formative assessment process that allows students to learn more thanks to the development of their metacognition and teachers to improve their praxis and educational proposal (Ortega-Quevedo & Gil, 2020).

Specifically, thinking will be promoted and recorded through thinking routines because of the positive effects of these resources in early learning experiences (Salmon, 2008). Routines are repeated procedures or patterns of action to make thinking visible, support the development of understanding, facilitate the achievement of goals, and manage interactions.... (Ritchhart et al., 2014). Depending on the moment, some or other routines will be used, and some thinking movements will be developed (Table 3). In addition, some routines will be carried out through a pictorial language that facilitates students to express their thoughts without the limitation of the educational stage linked to the development of reading and writing (García-Marigómez et al, 2021).

Objetives

Considering the need above to approach science in the Primary Education classroom from an innovative perspective that allows the development of scientific literacy of students from the early grades, the general objective of the research arises, which focuses on providing students with adequate scientific literacy that allows them to acquire a culture of thinking from the work of science in daily life. This objective is specified in the following specific objectives:

- Prove whether participation in a science programme improves attitudes towards science at a conative and affective level.
- Analyse whether participation in a science programme promotes understanding of the presence of rocks and minerals extracted from the ground we walk on in everyday products, the impact of their extraction and the need to reduce our consumption.
- Analyse whether participation in a science programme promotes the acquisition of thinking skills (like making connections, building explanations, and reasoning with evidence…) and knowledge about NoS&T (the scientist, the importance of tools, communication in science, and scientists' teamwork...).

For the development of the study, it is necessary to design, plan and implement activities and materials with scientific content that promote and facilitate the teaching-learning of science in an active and contextualised way through exploration and inquiry.

Methodology

Research Design

Throughout the project, we started from the ideas and inquiries of the project *Ciencia con consecuencia: la escuela y los maestros como fuente de cultura y vocaciones científicas* that aims to promote an educational change through school-university cooperation and innovation.

The research was framed in paradigmatic pluralism through a cross-sectional sequential explanatory design and exploratory scope, given that the theoretical moment reflected a great scarcity of studies based on intervention with science education proposals at early ages and with multilevel groups. The selection of a mixed method derived from the complexity of the research objectives and, therefore, from the need to obtain broad, solid and deep data.

In this sense, the quantitative phase had an evaluative and corroborative purpose, and the qualitative phase allowed us to describe and understand the educational phenomenon in greater depth. Both phases were analysed, as indicated below, at a descriptive level.

Participants

The sample consisted of 8 students from a multilevel classroom comprising the first and second grades of primary education (ages 6 to 7 years) of a rural public school located in a small town in the province of Segovia (Spain). This area's economic activities and services are very varied, and it has a rich artistic and cultural heritage. The centre welcomes 61 students whose families fall into a medium-low socioeconomic level (with some exceptions) and a cultural level that needs to be improved. The pupils present very diverse characteristics, with frequent educational needs if we consider the total number of pupils.

Therefore, the sample had a non-probabilistic nature for convenience. To solve problems such as those indicated by Ruiz & Ruiz-Gallardo (2017), the school and classroom were selected to avoid forgetting the rural school and the early educational stages in research and teacher training.

Data Collection Techniques and Instruments

Different quantitative and qualitative strategies and instruments were established according to the research objectives to carry out the data collection. For the quantitative phase, the questioning technique was chosen through the Leisure Time in Science (LeTiS) pictographic scale developed by Paños & Ruiz-Gallardo (2020), which was used as a pre-test and post-test. The selected scale is based on attitudes towards specific science learning experiences in non-formal settings. It has a high degree of unidimensional congruence, reliability, and validity, according to Barlett (208.7) and Kaiser-Meyer-Olkin (.798) and Spearman (>.95) statistics, respectively (Paños & Ruiz-Gallardo, 2020). The instrument includes eight items linked to interest (attitude) and eight to behavioural intention. Both dimensions have a three-point scale. Therefore, it is used as an instrument to evaluate students' attitudes before and after the intervention, that is, to corroborate the validity of the educational proposal to favour scientific vocations.

As for the qualitative phase, strategies such as systematic observation and analysis of the students' productions (thinking routines, student productions and self-assessment) were chosen. For this, a verbal scale was constructed with the different contents, skills, and attitudes about science by the objectives and included in the objectives of the didactic proposal. The items are formulated based on the official Spanish curriculum and the STS contents and reflect the evidence to be collected to assess the students' acquisition of scientific literacy (for further information, see Table 3). This instrument was applied to all learning products.

As for thinking skills, the rubrics of the work of García et al. (2017) were adapted to collect evidence on their acquisition and development. A rubric was designed for each of the thinking routines implemented. An example of this rubric is included in Table 1. In addition, to obtain more detailed information, complement the analysis of the students' productions and enrich the educational practice, a notebook was used by the teacher to record observations, and the cyclical moments of action research were used as a guide (Latorre, 2003).

Table 1. Rubric evaluation of the routine “Chalk Talk”.

Objectives	4. Highest level of achievement	3. Average level of achievement	2. Minimum level of achievement	1. Have not been achieved
Making conections	Makes connections between the elements of the routine and their prior learning.	Establishes connections between the elements of the routine.	Establish connections between some of the elements of the routine.	It does not establish any connection between the elements of the routine.

Procedure

The research began with the LeTiS test in a large group with the support of the researcher. Once the pre-test data had been collected, the researcher carried out the intervention. The group participated in a series of activities aimed, in general terms, at understanding that many products we use every day are made from rocks and minerals present in the soil we walk on, the impact of their extraction and the need to reduce our consumption because these resources are not infinite. An aspect that, far from being inconsequential, entails a series of negative effects on our lives and the planet. Therefore, it is essential to promote an education that teaches students to observe and learn about their environment and the relationship between society and nature to act critically and respectfully.

The approaches and methodologies used, as well as the characteristics of a small group, favoured participation and cooperation with other group members and the researcher herself. At the end of the activities, the LeTiS test was performed again as a post-test.

Data collection and intervention took place throughout four sessions of approximately sixty minutes each.

Development of the Didactical Proposal: Watch out, you're stepping on me!

To respond to the research objectives and the learning objectives stated throughout the text, an educational proposal is designed consisting of four phases (focus, exploration, application and reflection) and six interrelated activities that show the progression of knowledge to promote the connection of learning and the evolution of previous ideas (Table 2).

Table 2. Development of the Didactical Proposal.

Phases	Activities	Description
Targeting	Do you know me?	Motivation with a riddle and a map that directs students to a scavenger hunt (collection of rocks and minerals).
Explorationd and Application	Earth Detectives	We introduce the students to the activity by asking: Who are the detectives of the Earth? Then,using the "See-Think-Wonder" thinking routine, we encourage the students to manipulate, sense, and experiment with the materials. Next, we ask them where these materials come from and lead them to the answer of the Earth through brainstorming.
	Families of rocks	We will ask the students to make families of rocks in groups. Moreover, we provided them cards with the properties.This will help them make connections and expand their descriptions and ways of observing by discovering regularities. This activity will provide an adequate basis to briefly introduce the classification based on the origin of their formation through an audiovisual resource on the rock cycle.
	How do we obtain these resources	Activity based on the thinking skill "Compare-Contrast". This comparison is applied to two images before and after the construction of a mine. In this way, students can explore the consequences of resource extraction on the environment.
	Where or how do we use rocks and minerals?	First, the studens respond the question by using the routine “Chalk Talk”. Second, we propose that they explore and create a catalogue with drawings of the products and the rocks/minerals they contain. Finally we use the routine “Explanation Game” to reflect about the responsible consumption.
	Transfer of learning activity	The students will solve two problems using the “compass Points” routine and the knowledge acquired.
Reflection	Feedback	To check if the students have acquired the learning that we considered importante, their new concerns and possible changes in their attitudes or knowledge, we asked: • Would you like to know more about the topic? Would you have liked to do any other activity? • "I Used to Think... Now I Think? I Used to Do... Now I Do?"
	Assessment	Students visually represent the routine “Headlines” and fill out the self-evaluation form.

Data Analysis

The analysis of the data obtained through the questionnaires was carried out with the support of the SPSS Statistics V27 program. The program was used to organise the data and apply descriptive analyses to describe the information collected in a synthetic way to understand the variable and its evolution. That is, to facilitate comparing the results obtained in the pre-test and post-test. Specifically, for the descriptive analysis of the quantitative data, the median was used as a measure of central tendency (given that the selected instrument has an ordinal scale), measures of position through quartiles, variability (standard deviation), skewness and kurtosis. These statistics were applied to the two dimensions of attitude contemplated in the instrument: liking and behavioural intention.

The qualitative data analysis was performed by reading and detecting the aspects collected in the evaluation rubrics designed, which, as indicated above, are designed based on the contents of the official curriculum, the CTS consensus analysed in the theoretical framework. And then the evaluation of thought carried out by García et al. (2017). Therefore, the content analysis was based on a deductive process of locating categories and subcategories (Osses et al., 2006), given that the units of analysis were not emergent but were pre-established to identify information, compare, relate, and classify ideas. Table 3 summarises the categories and subcategories studied in the evaluation rubrics and the verbal scale. The table also includes the codes for each subcategory. These are used to quickly and easily add the evidence collected in the study to the results narrative.

Table 3. Pre-established categories.

Rubrics	Categories	Subcategories	Code
Contents for scientific competence	Epistemology	- Observation and classification of rocks and minerals - Identification of mines as a construction to obtain geological resources. - Identification of the soil as a resource site - Environmental impacts of mines. - Recognition of everyday products made from rocks and minerals.	- 1SC - 2SC - 3SC - 4SC - 5SC
	External Sociology	- Appreciates the work of geologists in our daily life - Appreciates the importance of reducing excessive consumption	- 6SC - 7SC
	Internal Sociology	- Acquisition of responsibility and active and respectful participation - Dialogue and use of sources to obtain information. - Express their ideas and emotions orally and in writing, reflecting on them.	- 8SC - 9SC - 10SC
Thinking Routines (Thinking Moves)	See-Think-Wonder	- Observing Closely and Describing What's There - Building Explanations and Interpretations. - Reasoning with Evidence - Wondering and Asking Questions	- 1STW - 2STW - 3STW - 4STW
	Compare-Contrast	- Observing Closely and Describing What's There - Uncovering Complexity and Going Deeply - Capturing the Heart and Forming Conclusions	- 1CC - 2CC - 3CC
	Chalk Talk	- Making Connections	- 1CT
	The Explanation Game	- Building Explanations and Interpretations. - Reasoning with Evidence - Making Connections	- 1EG - 2EG - 3EG
	Compass Points	- Uncovering Complexity and Going Deeply - Formulating Plans and Monitoring Actions	- 1CP - 2CP
	I Used to Think…Now I Think	- Reflexion y metacognition.	- 1UTNT
	Headlines	- Capturing the Heart and Forming Conclusions	- 1H

Results and Discussion

Results of the LeTiS Scale

In the data analysis process and the formulation of quantitative results, the study focused on examining the changes in students' attitudes after the intervention. For this purpose, as indicated above, the LeTiS scale used as a pre-test and post-test was analysed descriptively (Table 4).

Table 4. Descriptive analysis of the pre-test and post-test

Descriptive Statistical	Pre-test (n=8)	Post-test (n=7)

	Linking	Behavioural Intention	Linking	Behavioural Intention
Median (min=8 and max=24)	23,50	14,50	24	15
Standard Deviation	,744	4,071	,000	2,573
Skewness	-,824	,56		-,502
Kurtosis	-,152	-1,218		,605
Quartile 1	23	12		14
Quartile 2	23,50	14,50		15
Quartile 3	24	19,50		17

The initial results (pre-test) show that students predominantly accept or like science activities in informal settings. The median value of 23.50 is very close to the maximum score (24). In addition, other statistics such as the large negative skewness, position measures, standard deviation and kurtosis indicate a shift of the scores towards the maximum values with a small range (similar scores), which are linked to a liking for this type of activity in a majority way.

As for the dimension related to behavioural intention or predisposition towards informal scientific activities, we can observe that it has a less polarised behaviour. The median presents a medium value considering the maximum possible score (again, 24). Moreover, there is no great consensus as in the previous dimension. The value of the standard deviation and kurtosis reflects a greater variety of scores and, in addition, presents a more balanced distribution of values with a distribution close to symmetrical. Considering the position measures, we can affirm that 25% of the students present a low predisposition, 50% a medium predisposition and 25% a high predisposition to carry out activities of a scientific nature in their free time.

The final results (post-test) related to liking allow us to detect a slight improvement (since the initial results were very high) that directs the values towards the maximum score. The students show a great liking, acceptance or pleasure towards the scientific activities proposed in the questionnaire.

As for the predisposition results, we also observe a slight improvement if we consider the median value. The negative value of the asymmetry shows this slight change in values towards higher scores concerning behavioural intention.

In conclusion, it should be noted that the findings are in line with other studies using the LeTiS instrument. The results obtained by Paños & Ruiz-Gallardo (2020) also reflect a high attitude of the participants towards informal science with an average value, in their case, of 20.67. Regarding behavioural intention, we also observed a behaviour similar to that observed by Paños & Ruiz-Gallardo (2020). The students prefer to carry out other non-scientific activities during their free time instead of those proposed in the scale. This can be corroborated by the lower scores obtained in the items related to behavioural intention.

Results Related to the Didactical Proposal

The qualitative data analysis and formulation of results focused on examining the proposal's potential to improve the thinking culture and scientific literacy of the classroom and the students. Following the nature of action research cycles, this process was carried out in each session, considering the annotated observations and evaluation rubrics. In addition, this dynamic allowed us to analyse and detect possible educational obstacles to improve the approach and functionality of the different activities. The most relevant and enriching aspects of the implementation are presented below.

During the first session, the first two activities were carried out, and one of the main objectives was to observe how the students developed with the introduction of active methodologies. One of the main tasks was to guide them and provide them with the necessary scaffolding to work autonomously and creatively in teams.

In this first session, we were able to detect that the students were highly motivated by any activity related to science. In the first place, the initial motivational elements (riddle, the discovery of the rock collection, the geologist's story, and the identifications...) were effective in introducing the students to the subject and awakening their interest. Secondly, we can draw several results and conclusions from the "See-Think-Wonder" routine (Figure 2) by using the verbal scale to detect evidence of scientific culture and the rubric to detect the thinking skills worked in this activity.

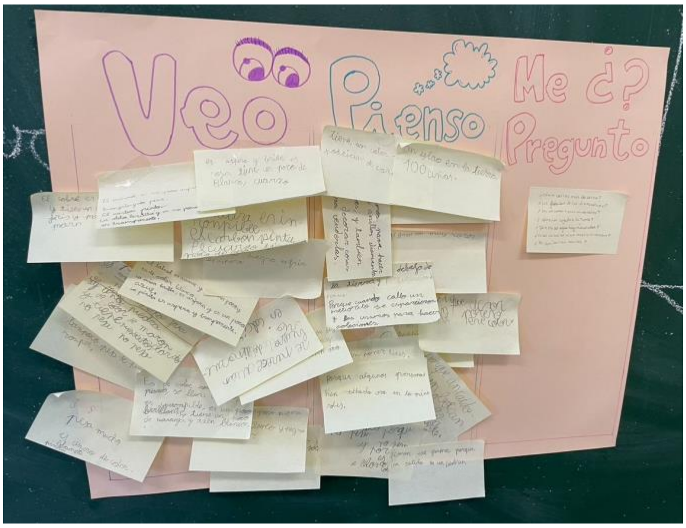

Figure 2. Cooperative "See-Think-Wonder" routine.

In the "See" section, the students were able to work autonomously by filling in their notes with their observations and descriptions (1SC, 1STW) (colours, shape, hardness, weight...) in detail: "It is pink, it is very heavy, it is called quartz", "the marble is a bit rough, and it is triangular", "the coal paints", "the halite shines and is transparent" ...

In the section "Think and Wonder", the teacher observed and wrote in his field notebook that the students presented difficulties in connecting ideas, constructing explanations, reasoning, and formulating questions (2STW, 3STW, 4STW). Therefore, several guiding questions based on the movements of thought had to be launched, thanks to which the students could follow the activity. About "Think", the students related the shape with the origin ("They have been on the earth a hundred years", "it has a strange shape. I think they have come out of a volcano", "the rocks are suitable for jewellery because of their colour" … and in the "I wonder" they showed interest in the uses, the origin, the fossils, the places where they can be found ("Do we use rocks in houses?", "do volcanoes have minerals?"), etc. As seen in the session, we begin the approach to rocks and minerals by connecting with the most easily identifiable uses and initiating connections related to their origin and the rock cycle (3SC, 5SC). The latter allows us to initiate the understanding of the dynamism of rocks and the Earth at an early age since, as Vílchez (2015) warns, this fact is one of the main challenges in the didactics of science and specifically in the teachings of the Earth.

Regarding other more transversal aspects (not linked to the contents and movements of thought), the teacher detected and noted in the field notebook that the students showed fatigue with the reading and writing process (“as the activity progressed, the pupils said they were tired of using the pencil while leaning back on the table”. The teacher also noted that the students were distracted during a partner's input by objects on their table or other partners (“they were individualistic”).

In the second session, the activity related to elaborating on families of rocks and minerals based on criteria established by the students. We obtained interesting results, as the pupils showed a certain skill in self-correcting and regulating their work.

At first, following the observations noted down by the teacher, when naming the families on the cards provided, some pupils focused on aspects not related to rocks but on comparisons with other elements ("cheese family"). However, the manipulative nature of the activity gave them feedback so that they could create appropriate groupings and names (1SC). When introducing other rocks and minerals, they could discover that the terminology was invalid because not all the white ones looked like cheese. Some of the families created were dark family, shiny, dotted, and transparent... Many pupils were surprised to discover that some rocks could be placed in two groups simultaneously. We did the task in two teams to expand the initial ideas.

After the sharing, we introduced the property cards for the students to characterise the families they had created in more detail. This activity was carried out quickly and smoothly as it involved visual and manipulative aspects.

After these activities, an informative video related to rock formation was shown. Many children were excited to see that their initial idea about volcanoes was true (3SC). Moreover, they recognised many of the rocks discussed in the video in the classroom. After this video, we asked the pupils how these resources are extracted. The pupils were not familiar with mines, so we watched the videos on mining and worked with the collage on the tools and technologies used. In assembly, we reflected on what the mines were like, what sensations we could feel inside them, the importance of the tools for working and what they were used for... Once the students had enough mining knowledge, we carried out the activity "Compare-Contrast" about the before and after of a mine.

The exercise was carried out following guiding questions because the pupils had difficulties focusing on one element and comparing it. As seen in Figure 3, the pupils represented through drawings and short sentences the differences related to nature, noise, landscape beauty, and pollution... (1CC), that is, the environmental impacts of mining (4SC). In conclusion, a very interesting debate, and a short controversy about the construction of mines arose. The students concluded that mines destroy the environment. Still, we need them to obtain rocks and minerals (2SC, 3SC, 4SC, 7SC). We therefore relate this situation to the 7Rs (Reduce, Reuse, Recycle, Repair, Redesign, Recover and Renew), a model that seeks to raise awareness of the need to reverse the destruction of the environment caused by infinite growth and unsustainable consumption that does not allow the ecosystem to maintain the cycles of matter and energy flows (Marten, 2001). Therefore, the students could describe the elements to be differentiated; they discovered the complexity (2CC) of the situation depicted and grasped the essentials to make judgements (3CC) by connecting learning.

Figure 3. “Compare-Contrast” thinking skills about the before and after of mining.

The third session was very enriching. First, in two teams, we carried out the routine "Chalk Talk" (Figure 4), answering the question, "Where or how do we use rocks and minerals? The observations of the teacher show that the students worked by taking turns to write autonomously ("All the students had ideas to tell in both groups, the students found that if they all spoke at the same time, they could not collect the answers in the routine and they took turns using a single pencil that rotated through the participants"). Their ideas on the topic were creative and interesting and showed a connection (1CT, 5SC) with their prior learning ("We use them for heating, making art, decorating, playing, building..."). Moreover, we could observe a great improvement related to cooperation and mutual help (8SC) (“Student A encouraged Student B with language difficulties to participate and write the sentence that he had commented to the group).

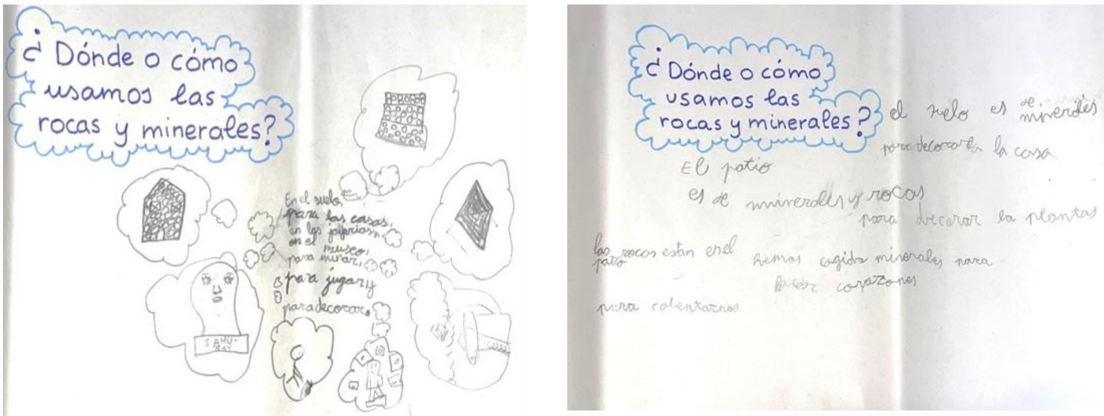

Figure 4. Routine “Chalk Talk” before the creation of the catalogue.

As for the creation of the catalogue of rocks and minerals, the teacher writes down that all the pupils participated actively and autonomously, demonstrating digital skills in the search for information (9SC) on the web (Figure 5) and artistically depicting everyday products and the rock or mineral of which they are composed (“All the pupils seemed motivated by the web and the drawing, and quickly got to work on their own. A couple of students asked for my help to read the information contained on the website”). In this activity, we begin to broaden the spectrum in which we catalogue the uses of rocks and minerals, giving visibility to some of them beyond construction, ornamentation, and jewellery (Laita et al., 2018). As can be seen in Figure 5, students have been able to discover the use of quartz in the manufacture of glass or bauxite in the manufacture of cans, the presence of coal in pencils, the use of mica as glitter in make-up, the consumption of halite and calcite in table salt and toothpaste respectively, etc. (5SC).

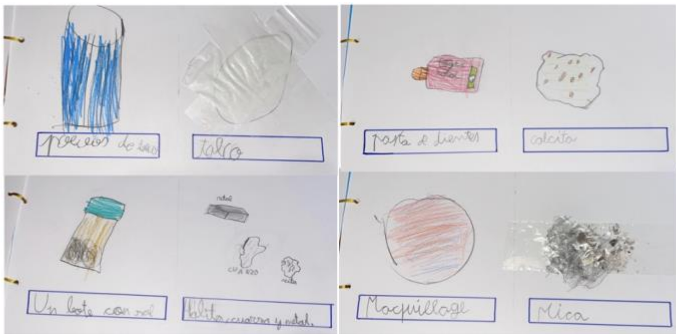

Figure 5. Catalogue of rocks and minerals elaborated by the students.

During the "The Explanation Game", the pupils participated in an orderly way. They could listen to and use the ideas of their peers to formulate new ideas or develop them more complexly (1EG, 3EG, 8SC, 9SC, 10SC). The teacher wrote in her notebook, "in this activity, I observed that the students listened to each other and responded by complimenting each other's answers or adding ideas. For example, Student C said that the rocks were part of our house and Student D added that they were the security of the earth". They concluded that in the catalogue, it should be noted that rocks are not infinite; therefore, we should use the 7Rs. At this point, we see another connection with the didactics of geology, as it reflects on the time and origin of rocks. Returning to the dynamism of the earth, students know that new rocks can originate from phenomena such as volcanic eruptions. At the same time, they are aware that we cannot control the creation of these phenomena (Vílchez, 2015). That is why some rocks are very old, and even some rocks and minerals, if exploited without control, can become scarce in areas where they were previously abundant.

Furthermore, students also showed the connection of this learning with the care of the Earth (2EG, 3EG, 7SC) ("We help the geologist to take care of the planet", "take care of rocks we need them to live, rocks are the security of the Earth", "rocks are not infinite, and neither are minerals, take care of them! We have to use the 7Rs"). To make the thinking visible and not lose the ideas worked on in this oral routine, they were put into a drawing with messages included in the catalogue (Figure 6).

Figure 6. Possible uses of the catalogue ad described by students.

In the last session, we carried out the transfer activity with the routine "Compass Points" in the group. The teacher states in her notebook again that the students can take turns and cooperate and that they found the routine complex ("The aim of the routine is complex, we had to make each cardinal point separately and explain in detail the statement beforehand"). In the situation related to the mine (Figure 7), they showed reflections related to consulting geologists (6SC, 2CP) (north element: what we need to make a decision) or to the destruction of nature by machines (5SC, 1CP) (west element: negative aspects of the situation). As positive aspects of the situation (eastern element), they stated that they would see more children in the village of families coming to work (the notes taken by the teacher explain that this situation is a common theme in the school and the village due to depopulation.). They concluded that they did not want a mine near their home (south element: what we decided) but that somewhere else, they would not mind. This shows the egocentrism typical of this age; they are not yet able to empathise.

Figure 7. Routine “Compass points” about the construction of a mine.

As for the one related to the choice of paper or aluminium foil (Figure 8), they showed a connection with the exhaustible nature of mineral resources. In the north element, students comment that paper comes from wood and aluminium foil from minerals. As a negative aspect (West element), they note that both materials wear out (5SC, 1CP). The idea gathered in the East element (positive aspects) that paper can be used both as a snack wrapper and as a napkin (2CP, 7SC) led them to conclude that paper is the best option.

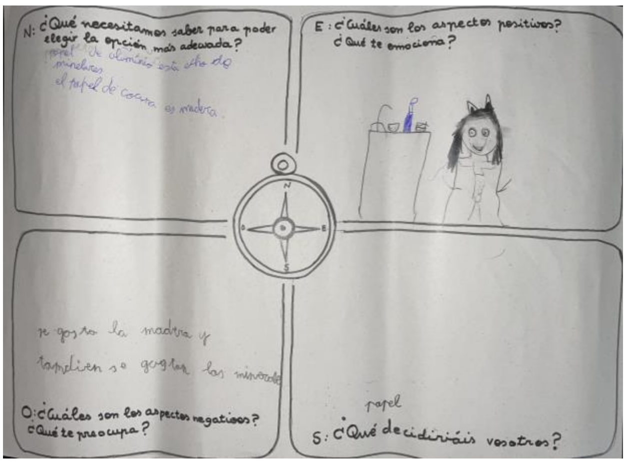

Figure 8. Routine “Compass points” about the choice of paper.

For the final feedback, we organised an assembly in which all activities were recalled before starting. The pupils present the ideas they have learnt and enjoyed during the project. Regarding the concerns aroused by the project, they highlight the desire to build their rock and go out to look for rocks and minerals like geologists do (1UTNT).

About the routine "I Used to Think... Now I Think", all the ideas (collected by the teacher in the field notebook) can be summarised as an increase in knowledge about the uses of rocks and minerals and a change towards an attitude of respect and care for the materials we use every day so as not to waste them. They express concern about misuse.

Then we completed the self-assessment carried out by each learner (Figure 9), a lack of self-criticism was detected due to the limitations of their developmental stage. All the pupils stated that they enjoyed the process and felt good during it (item “I felt good during the project” and “I found the activities interesting”).

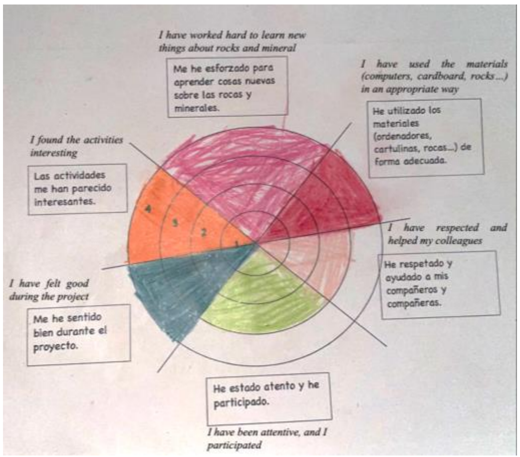

Figure 9. Sell-assessment target.

Finally, we carried out the routine "Headlines" through a drawing (adapted from Ritchhart et al., 2014). In their representations, the students reflect on the moments they have experienced and their feelings. The drawings were varied: there was a representation of the most striking rocks and minerals, a portrait of the classroom members as geologists with their tools (Figure 10 left), a drawing summary of the activities we had carried out (Figure 10 right), representations of the nearby landscape where the students had observed rocks such as those studied, drawing with poetic phrases like “I am a heart mineral” and drawings of the rocks and minerals that we had studied…

Figure 10. Pictographic headlines produced by the students at the end of the project.

In short, the activities have been developed appropriately, creating an ideal scene for the pupils to explore autonomously and construct new learning. The difficulties they may have had in guiding and making their thinking visible are not something to worry about, given their young age. However, it should be noted that work from an early age will allow them to evolve.

Conclusions

The results show that the aspects considered in the literature review and the current socio-educational analysis have made it possible to carry out a design of activities and materials suitable for responding to the objectives set and to the educational and evolutionary needs of the students. During the evaluation of the intervention, it has been verified that thanks to the didactic design implemented, pupils have understood that rocks and minerals are present in products, materials, environments... of our daily life, that their extraction causes impacts on the environment and that, for this reason, we must reduce their consumption. Students have developed their thinking skills and gained a broader view of science thanks to the NoS&T content. Consequently, the didactic proposal promotes a culture of thinking from the work of science in everyday life.

Applying the enquiry methodology, focusing on what students need to know, has made it possible to promote a scientific culture for life. In other words, by discovering their lack of knowledge about the origin of the resources we use daily, we have introduced enquiry so that pupils can see the world scientifically through simple objects such as those included in the catalogue of uses of rocks and minerals. Furthermore, the use of routines and the results obtained in these routines show that pupils have been encouraged to ask questions and make reasoned predictions, explore data, and organise their discoveries to draw scientific conclusions about elements present in their immediate environment.

Therefore, the implementation of the proposal offers us evidence of the potential of the aspects taken into account in its design to facilitate the teaching-learning of science, promote the acquisition of the selected NoS&T contents, and favour the creation of a culture of thinking. This is the first step for students to begin to develop their scientific thinking to act in a reasoned environment, as they have shown that they can go beyond the simple contemplation and classification of rocks and minerals as geologists do, building their knowledge from their previous ideas. In particular, they have begun to understand the rock cycle and the dynamism of the Earth. They are beginning to look beyond the uses of rocks and minerals in ornamentation, construction, and jewellery.

On the other hand, the results derived from the comparative analysis of the pre-test and post-test do not allow us to conclude robustly that the proposal favours positive attitudes towards science. The results allow us to glimpse the potential that the selected contents on NoS&T, the motivational elements included, the use of active methodologies and the visibility of thinking that allow the teacher to dedicate more time to attending to diversity, generating a suitable climate, motivating, detecting difficulties... must favor positive attitudes and, therefore, scientific vocations. This idea is reinforced by the positive assessment of emotional and attitudinal aspects in the self-assessment target (item: "I felt good during the project") and in the learning outcomes detected through the content and thinking routines rubrics.

In terms of possible limitations, on a qualitative level, although the results show the usefulness of the proposal, it would be advisable to address the transferability criterion by implementing the proposal in other contexts with the appropriate flexibility to cater for the particularities of the students. At a quantitative level, the main limitation is the size and non-probabilistic nature of the sample and the limited time dedicated to the intervention. Therefore, the prospects following the study's ideas are directed towards achieving a complete study through new, more extensive implementations temporarily to obtain more conclusive and generalizable results. This line of research is in line with the project in which the study is framed, which is committed to promoting science for life that favors positive attitudes towards this field of knowledge.

Finally, it should be noted that the study offers us a vision of certain educational implications. The intervention shows that science can and should be taught early, as the activities developed are easily included in the classroom. Teachers must consider the absence of elementary content in the curricula and the importance of starting from the interests and realities of the students to show close and useful science.

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