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The chemistry club as a space for promoting the scientific spirit

O clube de química como espaço de promoção da mente científica

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Resumo: Este artigo explora o desenvolvimento da mente científica dos participantes de um clube de química por meio da aplicação de atividades teóricas e práticas de investigação baseadas na epistemologia de Gaston Bachelard. O clube de química foi estruturado a partir do desenvolvimento de atividades de investigação nas quais os participantes foram supervisionados por monitores que lhes deram o apoio necessário nos processos de investigação. A análise dos dados foi realizada por meio de uma triangulação dos dados obtidos a partir dos questionários respondidos pelos participantes do clube durante as atividades. Os resultados obtidos mostraram que o envolvimento dos participantes nas atividades do clube de química aumentou seu interesse em explorar suas ideias e conhecimentos de ciência e química. Os participantes usavam respostas curtas e superficiais para explicar fenômenos científicos; porém, após a participação nas atividades, os participantes passaram a explicar fenômenos científicos utilizando conhecimentos e conceitos mais aprofundados.

Palavras-chave: clube de química, abordagem investigativa, espírito científico, Gaston Bachelard.

Abstracty: This article explores the development of the scientific mind of participants of a chemistry club through the application of theoretical and practical inquiry activities based on the thoughts of Gaston Bachelard. The chemistry club was structured based on the development of inquiry activities where the participants were supervised by monitors who provided them with the support they needed in the inquiry processes. Data analysis was conducted through a triangulation of the data obtained from the questionnaires responded by the club participants during the activities. Results show that the participants' engagement in the chemistry club activities boosted their interest in exploring their ideas and knowledge of science and chemistry. Participants used to give short, superficial answers to explain scientific phenomena; however, after their participation in the activities, they began to explain scientific phenomena using more in-depth knowledge and concepts**.**

Keywords: chemistry club, inquiry approach, scientific mind, Gaston Bachelard.

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A seção "Cadernos de Pesquisa" é um espaço dedicado exclusivamente para artigos inéditos (empíricos, de revisão ou teóricos) que apresentem profundidade teórico-metodológica, gerem conhecimentos novos para a área e contribuições para o avanço da pesquisa em Ensino de Química.

Studies have shown that although the majority of the population in Brazil has considerable interest in science, they have little knowledge and information about science (Takahashi and Tandoc, 2016). According to the findings of a research conducted by Villani *et al.* (2010), although 61% of the study participants in Brazil said they had an interest in science, only 20% of them knew the name of a scientific institution in the country (Villani *et al.*, 2010).

In Brazil, the dissemination of scientific knowledge primarily occurs through museums, science centers and magazines. Unfortunately, given the low investment in science and the limited sources of scientific knowledge dissemination in the country, only a tiny portion of the population has access to scientific knowledge and sources of scientific knowledge dissemination. Cazelli and collaborators discuss in their works the need to implement science museums in the Brazilian context, also as a way of extending scientific dissemination and science teaching. The authors also state that, at the present time, it is essential to develop works that can discuss the issues, challenges and possibilities that are fulfilled for museums (Cazelli *et al.*, 2003).

As pointed out in the literature, scientific culture can only be developed when one has a reasonable understanding of scientific concepts and the steps involving the construction of scientific knowledge (Hodson, 2003; Hurtado; Cerezo, 2012; Tala and Vesterinen, 2015). This fundamental understanding allows one to perceive that knowledge is constructed through discussions and should not be transmitted as absolute truths (Tala and Vesterinen, 2015). According to epistemologists, in order to bridge the gap between scientific knowledge and the individual's reality, there is the need to replace simplistic and immediate thinking with a deeper thinking that involves the simultaneous development of rationality, idealism, empiricism, and imagination (Bensaude-Vincent, 2005; Chimisso, 2001; De Lima Mascarelo *et al.*, 2021; Lima and Marielli, 2011); in this way, the students will be able to appreciate the true dynamism of science while striving to construct their scientific knowledge.

In order to gain a holistic understanding of what scientific culture is, the term can be better interpreted under the concept of Bachelard's *esprit scientifique,* which is translated literally from French as scientific spirit (Bachelard, 1996)[i]. For the philosopher, spirit refers to a behavior, a characteristic that develops in people who incorporate specific attitudes and a way of thinking into their daily lives. In the case of the scientific spirit, the individual starts to live and relate to the world and to people through the adoption of attitudes that are typically related to scientific thinking. For purposes of illustration, the scientific spirit in people can be associated with the following: their profound interest in understanding their reality in greater depth; their preference of asking questions over providing answers and not easily accepting what is offered them without any room for criticisms; and using reason and logical reasoning to make their decision.

Some authors use the term "scientific mind" instead of "scientific spirit" to refer to this scientific way of thinking (Fedi, 2017; Stoltzfus and Smith, 2017). Although both terms are correct, their literal translation can be misleading in other languages or in epistemology (Krugly-Smolska, 2001). To avoid such terminological misunderstanding, in the present work, we use the term "scientific mind" instead of "scientific spirit" because it conveys a more appropriate meaning when one thinks of "scientific culture".

According to Bachelard, having a scientific mind is not just about eliminating contradictory possibilities and finding a unique and commonsensical explanation about a given phenomenon (Bachelard, 2009)[ii]; when one appropriates the forms of scientific knowledge construction, they develop the habit of dialectic thinking, searching for other variables and possible ambiguities in phenomena.

For the philosopher, the development of the scientific mind primarily occurs through three stages/states (Bachelard, 2009; Marcondes *et al.*, 2017), as shown in Table 1. Based on their characteristics, the states are regarded possible indicators of scientific development of the individual, and these states can be used to evaluate the individual's incorporation/appropriation of scientific reasoning into their mindsets.

Table 1: Description of the three states and the main characteristics of each state involving the development of the scientific mind of an individual, as proposed by Bachelard.

STATES	CHARACTERISTICS
Concrete	The mind satisfies itself with simplistic explanations and it is content with the visualization of flashy phenomena.
Concrete-abstract	With the exercise of learning to question and perceive one's errors as an opportunity for growth and maturity, the individual can transcend into the concrete-abstract state when the mind begins to feel more secure from its abstraction.
Abstract	The scientific mind adopts a critical posture in relation to the information it receives and the explanations available, seeks new sources of verification for the ideas presented, and takes pleasure in this process of exercising the mind in the face of a problem.

Studies reported in the literature have shown that the use of alternative environments, other than schools, for the teaching of science based on the systems thinking approach is highly promising for the effective learning of science and chemistry (Eshach, 2007; Godínez Castellanos *et al.*, 2021; Lasker, 2019). In particular, the use of non-formal spaces for the dissemination of scientific knowledge allows one the freedom to learn without the rules and constraints of the school and offers people the opportunity to learn in an environment free from the pressure of curriculum compliance; this lack of pressure helps reduce the perception that it is difficult to learn chemistry and boosts students' interest in pursuing and continuing their studies in the STEM (Science, Technology, Engineering, and Mathematics) fields. Reports in the literature show that the fun promoted in these environments – science clubs – helps stimulate the participants' interest in science, apart from boosting their self-esteem and confidence (Bopegedera, 2021; Godínez Castellanos *et al.*, 2021).

As pointed out above, science clubs have great potential to be employed as suitable spaces for the promotion of activities related to scientific knowledge dissemination. The participants can be actively engaged in the performance of the activities held in the clubs with freedom of action, without the pressure imposed upon them in formal learning environments. These non-formal spaces can be used for the development of scientific culture and the popularization of science, making it more accessible to people from different backgrounds. The question that this research seeks to reflect upon is: what is the contribution of a chemistry club to the formation of a scientific mind?

Methodology

This investigation has a qualitative character, perspective of research based on the inquiry approach and the formation of the scientific mind discussed by Bachelard. A number of studies reported in the literature show that there are different degrees of inquiry openness related to the responsibilities of the participants at each moment of an inquiry activities, proposed guidelines with different levels of inquiry that can be applied across multiple disciplines to help the teachers and researchers guide the activities performed with the students and the communication between one another. Such guidelines are intended to help avoid the confusion associated with the varied uses of inquiry currently found in the literature (Banchi and Bell, 2008; Blatti *et al.*, 2019; Cuevas *et al*., 2005). Table 2 summarizes the different degrees of freedom that can be granted to participants (Kasseboehmer *et al.*, 2015).

The Chemistry Club is an extension activity developed by a Brazilian public university and which is held semi-annually since 2015. Figure 1 provides an outline of the integral parts of the club along with its areas of operation. The only restriction for participation in the club is age – the participants were required to be over 15 years old.

The announcement about the opening and functioning of the chemistry club was made in schools and public places. To inform the public about the chemistry club, the posters and other dissemination materials employed contained an explanation about what the chemistry club is, how it functions, and encourage the public to search people who were interested in taking part in the activities and discussions that would be performed in the club.

In the year 2016, the chemistry club had 14 participants: 7 girls and 7 boys, but only 10 participants took part in the activities until the end. Therefore, for the present research, we present the responses of 10 participants who attended the meetings and participated in all activities. All the students

Table 2: Levels of inquiry according to the freedom given to participants.

Level	Materials	Problems	Procedures	Data Collection and Analysis	Conclusions
0	Provided	Provided	Provided	Provided	Provided
1	Provided	Provided	Provided	Provided	Open-ended
2	Provided	Provided	Provided	Open-ended	Open-ended
3	Provided	Provided	Open-ended	Open-ended	Open-ended
4	Open-ended	Provided	Open-ended	Open-ended	Open-ended

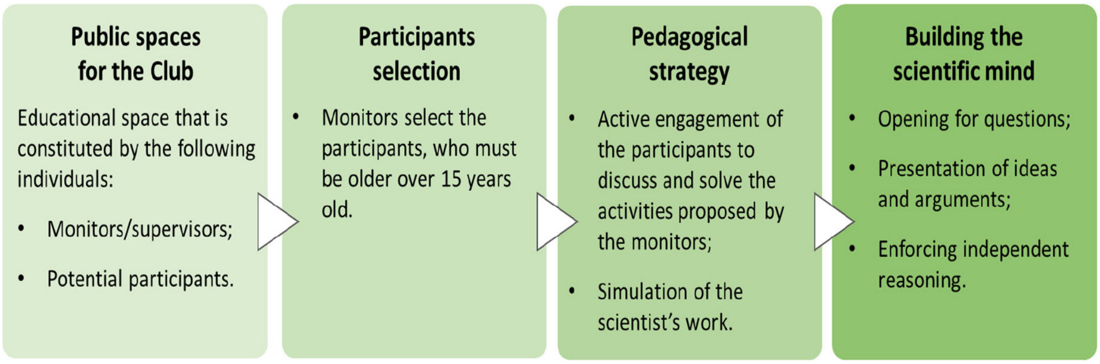

Figure 1: Representation of the methodology developed for the construction of the chemistry club: public spaces for the club; participants selection; pedagogical strategy; building the scientific mind.

were in high school in the city of São Carlos, state of São Paulo, Brazil. Their school hours were at opposite times to the activities of the club. Two students were from public schools: *Escola Técnica Estadual de São Paulo – ETEC Paulo Botelho* (Paulo Botelho State Technical School of São Paulo) and *Escola Estadual Jardim dos Coqueiros* (Coconut Tree Garden State School). Other eight students were from a private school maintained by the Industry Social Service (Serviço Social da Indústria - SESI). Some participants declared interest to participate in the club during lectures on science communication promoted by the University of São Paulo – USP. The students from SESI declared that they had previous experiences with investigative activities in chemistry classes, which may also have increased their interest in the club.

The initial activities were intended to encourage the participants' active engagement in theoretical and practical inquiry activities. In open-ended and exploratory activities, it is essentially important to create a supportive and open atmosphere for students to develop ideas and promote an interactive environment which enforces scientific thinking; by doing so, the participants will develop relevant characteristics and skills that will allow them to overcome and solve the challenges proposed in the activities (Blatti *et al.*, 2019). The first two meetings were used to evaluate the participants' knowledge of science based on how the scientist deals with a problem and to better acquaint the participants with some laboratory equipment and glassware; this familiarization process helped the participants feel more comfortable to participate, since most of them had never set foot in a laboratory before. The explanations provided regarding the functions/uses of the glassware in the laboratory served as "pieces" for the participants to assemble the "puzzle" of the inquiry.

Considering that most of the participants had never performed an experiment or been involved in scientific inquiries, the inquiry was initiated using experiments of lower degrees of freedom – see Table 2. Through these experiments, the participants were able to develop some relevant skills required of a scientist and be familiar with scientific procedures and laboratory instruments. In this stage, two level 2 activities were applied, where the script was provided for the participants to collect data, analyse the data collected and draw up a conclusion. One last activity was applied where the participants were required to propose a procedure to solve the problem presented using the materials they were provided – this corresponds to level 3 in Table 2.

From the third meeting onwards, the participants had the opportunity to experience the first level 4 inquiry activities; at this level, the participants were free to propose their hypotheses and choose which materials and reagents they need to use to perform the experiments. Seven level 4 activities were applied.

To perform the activities in the chemistry club, the participants were allowed to work individually and in pairs; they had the opportunity to initiate discussions and state their thoughts, hypotheses, methodology, and conclusions about their inquiry.

After proposing the hypotheses in the theoretical part and the experimental procedure in the practical part, the participants were allowed to present their ideas and discuss the relevance and coherence of these ideas. The monitors ensured that the participants' opinions were fully respected and the participants' ideas that seemed incoherent or inappropriate for solving the problems were put forward for discussions as part of the active learning process targeted at the construction of knowledge, as it occurs with scientists.

Data collection instruments

Although Bachelard does not establish a pedagogical framework to support the construction of the scientific mind, the philosopher points out that phenomenological studies which start from images that are considered easy and familiar can encourage the individual to propose original and unusual hypotheses, and this helps promote one's evolution from the concrete state. In this context, the main objective here is to discuss how the epistemology of Bachelard can help understand the variables involved in the student's arguments, as well as the form, the why and how the participants can develop a scientific mind inside the Chemistry Club, through the application of a qualitative analytical technique (Chin and Osborne, 2008; Merriam and Grenier, 2019; Pazinato *et al.*, 2021).

Data collection and analysis were performed in the 9-week period during the meetings held in the chemistry club; the collection and analysis of data were carried out based on the triangulation of data (Bekhet, 2012). Based on the epistemological observations mentioned above, initial, and final questionnaires were prepared and applied in the first and last days of the chemistry club meetings, respectively. The questions were prepared in order to qualitatively assess the scientific state of mind of the participants before and after taking part in the meetings at the chemistry club. The questionnaires consisted of open questions, which required interpretation of figures. The sheet presented the following question:

"What phenomenon is represented in the images? Explain the phenomenon based on your knowledge. Use everything you have learned at school and outside school".

The images presented included the following: a boat on a beach, a burning matchstick, and two molecules in agitating state. The theoretical inquiry approach was chosen and applied in the activities of the club, aiming to allow the participants to have the freedom to propose and develop hypotheses, without fear of presenting arguments that could be considered wrong, and to avoid seeking to answer a question by trial and error. It was expected that the students tried to answer with arguments that went beyond the macroscopic look, that they reflected on the phenomena, and that they could use previous knowledge

(Cazelli *et al.*, 2003). With these goals in mind, the monitors elaborated the theoretical investigative activities by adapting them from the textbooks approved by the Textbook National Program (Programa Nacional do Livro Ditático - PNLD).

Fieldnotes were used to record the progress of the scientific mind of the participants. Changes in behavior regarding participation and changes in attitudes related to the scientific mind were observed. Furthermore, the answers provided individually by the participants in the initial and final questionnaires, the reactions of the participants during the club meetings, the development of arguments, the employment of scientific terms, the construction of hypotheses, and the progress of the scientific state of the participants were all observed and analysed by the two chemists, one man and one woman, researchers of science communication at the São Carlos Institute of Chemistry (IQSC-USP). This analysis was conducted based on studies previously reported in the literature (Pazinato *et al.*, 2021). Figure 2 provides a simplified illustration of a data collection step.

Discussions

The initial questionnaire

The responses provided by the participants in the initial questionnaire indicated that the participants were in the concrete scientific state, while the responses they provided in the final questionnaire showed noticeable changes in the scientific reasoning of the participants – this pointed to the development of the scientific mind. Apart from the questions that were used to test the participants' knowledge of basic scientific concepts in chemistry – such as the notions of chemical and physical transformations – the other questions in the questionnaire were intended to evaluate the following: how the participants expressed themselves when it comes to elaborating an explanation for a given phenomenon; the participants' usage (or not) of scientific concepts when explaining a phenomenon; the participants' interest/concern in describing their hypotheses in a more or less detailed manner or exploring more than one possibility when explaining a given phenomenon. Considering that the traditional classes do not usually stimulate the development of the scientific mind of their students in an active way, the evolution observed in the participants' scientific mind was attributed to their participation in the chemistry club.

The fact that the participants began to use more scientific concepts and ideas to elaborate their explanation about a given phenomenon indicated that they were concerned with providing better explanation and having a better understanding of the phenomenon – in other words, the participants demonstrated curiosity and value for scientific knowledge. According to Bachelard, an epistemologist must capture the scientific concepts into progressive psychological syntheses, establishing a scale of concepts for each of these syntheses, showing how one gives rise to the other and how they connect. By doing so, the professional will then be able to evaluate the epistemological efficacy of the scientific concepts (Bachelard, 1996). Although few comprehensive investigations were performed in order to adequately capture the pronounced changes that occurred in the responses provided by the participants in the initial and final questionnaires, the results obtained in these investigations showed that the participants experienced a positive change. As pointed in the literature, when people come to understand how scientific knowledge is constructed, they begin to consume this knowledge more and be more critical to knowledge (Camara *et al.*, 2018), and this inevitably helps accelerate the development of the scientific mind.

The first question presented to the participants had images of chemical and physical phenomena, and the participants were

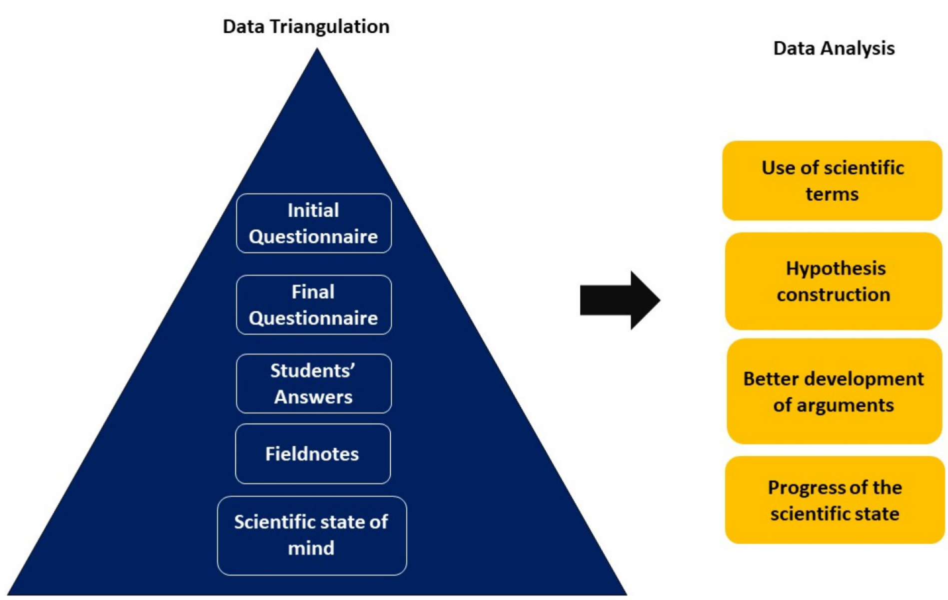

Figure 2: Steps involving data triangulation and analysis.

required to explain these phenomena based on their previous knowledge. For the analysis of the participants' responses, we considered how the participants explained the phenomena and whether they employed scientific terms to explain the phenomena. Of the three images, the participants were only able to provide a more elaborate explanation on the image showing an oxidized metal. The answers provided by the participants in all club activities are identified here by numbers (Participants 1 to 4) to preserve the identity of them and to ease the reading of this article.

One participant attempted to explore the image of the boat on the beach and the knowledge acquired previously to elaborate a sound explanation regarding the phenomenon a boat on a beach. Below is the transcript of the response:

"The boat in the image illustrates degradation; it shows a rust of its metal (material). This occurs due to the contact of the salt (saline) water with the metal of the boat, causing a reaction that wears that metal" (Participant 1).

The other participants gave brief explanations about the phenomenon, using few words and concepts: "*The boat is rusting and is in decay"* (Participant 2). In the image showing combustion, one participant only wrote "*phosphorus combustion*" (Participant 3). The participants found the last image, which contained a submicroscopic representation of water molecules before and during the boiling phenomenon, the most difficult to explain. Only two of the participants provided a reasonable response/explanation about the phenomenon, and their answers consisted of a brief explanation that did not explore the concepts as in the other images. Another participant gave the following answer, "*Molecules of water evaporating*" (Participant 4).

The explanations/responses that the participants provided in the initial questionnaire consisted of brief simplistic concepts; this way of explaining scientific phenomena can be assumed to the fact that the participants were trying to remember what they were taught at school by providing a "memorized" answer to explain the phenomena (purely based on rote learning). This may reflect how science is taught in their schools. According to Hodson (1992), in this teaching approach, since the curriculum does not go hand in hand with the real needs of the students, there is no adequate reflection about the contents, and all the teaching process boils down to the transmission of knowledge through rote learning, which has no effective value to the apprentice (Hodson, 2003).

With regard to the use of scientific terms, in general, the participants were found to employ one or two scientific terms in their explanations. The terms used were primarily intuitive; for instance, in the image containing fire, the most cited term was "combustion". In the case of the image containing a boat on the beach, the terms "degradation" and "rust" were cited more than "oxidation". For the last image, which showed two molecules in agitating state, the participants cited particles, molecules, and chemical reactions. For the analysis of the scientific mind of the participants in this first pre-club moment, as pointed out above, the explanations provided by the participants to explain the phenomena were brief, simple, and fast. In their study reported in the literature, Pazinato *et al.* (2021) evaluated the construction of scientific knowledge in high school where they showed that the majority of the answers provided by students in the initial questionnaire were of common sense, subjective and realistic; this observation is found to be perfectly in line with the finding of the present research. According to Bachelard, it is typically characteristic of the pre-scientific mind to satisfy itself with quick explanations about phenomena (Bachelard, 1996). These short responses presented by the participants prior to their engagement in the activities in the chemistry club are clearly indicative of their concrete scientific state, as pointed out by Bachelard (1996).

The final questionnaire

Compared to the initial questionnaire, in the final questionnaire, the participants exhibited considerable improvements in their scientific state of mind; the participants explored more concepts and ideas in their explanations about the presented phenomena. As it can be observed below, the following participant's response about the image with the boat consisted of a more elaborate explanation for the phenomenon – with the inclusion of the hypothesis that the boat had been in that place for some time:

"*From the image, you can see that the ship has been standing in the same place for a long time and because of the oxidation, the boat has become rusty and damaged*" (Participant 2).

In general, the participants' responses to the questions in the final questionnaire were more elaborate and thoughtful than in the initial questionnaire; they used more detailed information to answer the questionnaire and even tried to create hypotheses aimed at explaining the phenomena they were questioned about, as shown by participant 3 about the burning matchstick:

"In the image it can be seen the combustion of the fire match with the oxygen making fire as a result" (Participant 3).

Regarding the image illustrating the molecules, the response given by one of the participants was more elaborate, providing three concepts to explain the phenomenon in the image. Although the explanations given by the participant were simple (as the respondent did not deeply explore and explain the concepts), it clearly showed that the respondent tried to explore the knowledge acquired through the club activities:

"*It can be (related to) the separation of some substance or the evaporation of some substance or the mixing of two substances*" (Participant 4).

Although the answer given by the participant was still devoid of meaningfully complex scientific reasoning, the respondent made some inferences related to experimentation, which is a feature of empiricism or an evolution from concrete-abstract state to abstract (Pazinato *et al.*, 2021).

About the activities

During the execution of the activities, some signs of changes were observed in development the scientific mind of the participants. At first, the participants were unable to explore the information provided and did not actively engage in the discussions. After some meetings, the participants began participating actively in the discussions (as they found the discussions to be enlightening and thought-provoking), seeking to explore the information provided, questioning the tutor, and striving to elaborate their hypotheses and validation procedures. The participants' active engagement in the activities and discussions showed that the students were able to develop scientific skills and habits after taking part in the inquiry activities (Hofstein *et al.*, 2005). Essentially, this drastic change observed in the participants' behavior points to their scientific maturity. The skills and experience they acquired during the discussions and resolutions of the problems resulted in a paradigm shift whereby the students began to show clear signs of cultural change – scientific mindset; this outcome is in line with some works reported in the literature (Minner *et al.*, 2010; Tala and Vesterinen, 2015).

When one analyses the first activity in the theoretical part, one will observe that all the answers given by the participants are characterized by low order cognitive abilities – know, describe and remember (Zoller, 1993; Zoller and Pushkin, 2007). According to Bachelard, these are characteristics of a mind that is situated in a state that is intermediary to the scientific mind, since the scientific mind requires one to see, perceive the phenomena and arrange the important events in series (Bachelard, 1996). The answers presented by the participants fall under the characteristics of the concrete state, with the demonstration of enthusiasm about the phenomena and limiting their thoughts to the visual and the first images of the phenomenon.

Similar results were obtained during the practical aspect. The participants were found to be confused about what a hypothesis is and the procedure they could use to validate the hypothesis. Although the concepts of hypothesis, procedure, results, and conclusions had been covered in the initial meetings, this experience was unprecedented to the students because it was the first time they were challenged to think freely – with a high degree of freedom. So they were expected to feel insecure when elaborating their responses. Here, one can clearly observe one of the characteristics of the pre-scientific mind discussed by Bachelard. At the pre-scientific mind state, one is satisfied with quick responses and the mere execution of the experiment or the observance of its execution makes the person feel satisfied already; there is no doubt nor speculations, and the mere look at the macroscopic phenomenon is fine, since one does not feel the need to contemplate about the phenomenon in order to come up with some reasonable scientific understanding, explanation and questioning about why and how the phenomenon occurs (Bachelard, 1996).

Compared to the initial activities, better results were obtained in the final activities. In the theoretical part, the participants began to explore more information, providing in-depth explanations in their answers. The participants' answers contained more scientific concepts and terms, along with reasonable explanations about the rationale behind.

In the last theoretical inquiry, although the participants made no significant changes in the conceptual explanations they gave in their responses, they employed more scientific concepts and terms to explain the phenomena. The participants explored the knowledge and information provided, and they demonstrated that they were reasoning more deeply than they did at the beginning (Guest *et al.*, 2006). The participants realized that the answers were supposed to be constructed based on the whole knowledge they have acquired and not in a simpler and less thoughtful way as they did in their schools. This observation is perfectly in line with the study reported by Tala and Vesterinen (2015) who shed light on the individual's understanding of the nature of science. According to these authors, the individual needs to understand how scientific knowledge is constructed and thus understand that scientific knowledge is not made of absolute truth.

Based on the fieldnotes recorded during the activities, we were able to assess any indication of transformations. The fieldnotes pointed to changes in the behavior of the participants. After taking part in the meetings at the chemistry club, the participants began to use more scientific concepts and to question more about the phenomena that occur around them; in addition, the participants appeared to be more involved with scientific issues. This behavior shows that the scientific mind of some of the participants may have evolved, leaving behind some characteristics of the concrete state, such as the enthusiasm and fascination one demonstrates at the first sight of images of a given phenomenon (Pazinato *et al.*, 2021).

Although the participation of the students in the activities of the club was considered positive, the teachers in schools suggested that in future actions, the activities of the club could occur for a longer period of time so that more impacts on the students could be observed. Another difficulty in the development of the research was maintaining a composition of the group of students because new students started after the first activity and others skipped some activities.

The monitors described that during the first activities of the club, the students seemed to be confused with the investigative method in which they had the freedom to propose hypotheses and validations. It is believed that this behavior occurred because it is a different type of activity from what is traditionally proposed in schools.

Conclusions

The Chemistry Club was designed to be a space where participants could experience theoretical and practical inquiry activities, with the freedom to reflect, elaborate hypotheses, discuss and test their ideas, and become the protagonists in the construction of their knowledge. The club promoted a didactic and dynamic environment where the mediators supervised the participants in the validation of their hypotheses through dialogue and observation and stimulating discussions between the participants and their peers. The objective of the club with inquiry activities was to make the participants feel as if they were scientists involved in experimentation targeted at the construction of knowledge, experiencing scientific reasoning, using scientific procedures to validate their hypotheses, and drawing their conclusions.

The results obtained from this research show that when students are given the opportunity to take part in theoretical and practical inquiry activities conducted in a chemistry club, this induces the development of their scientific mind – which answers the central question of this research. The participants' records showed that the participation in the Chemistry Club helped the participants explore their ideas in a deeper manner. While in the beginning the participants gave quick answers about the phenomena they were presented, using very few concepts to explain the phenomena, in the final stage of their participation the participants were found to apply more in-depth knowledge and additional concepts to explain the phenomena.

The findings of the present research show that the conduct of inquiry activities in a Chemistry Club can help the scientific mind of the participants to evolve from the concrete state – the state at which the individual demonstrates enthusiasm and fascination at the first sight of a phenomenon, providing immediate, simplistic and less thoughtful responses to explain the phenomenon – to the concrete-abstract or abstract state.

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Notes

[i]BACHELARD, G. **La formation de l'esprit scientifique** (1938).

[ii]BACHELARD, G. **La Philosophie du non - Essai d'une philosophie du nouvel esprit scientifique** (1940).

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