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Science communication in unexpected places

ARTICLE

Exploring chemistry: the impact of an interactive chemistry model on student motivation in non-formal education spaces

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Abstract

The negative image of Chemistry that students have, associated with chemophobia, reflects the decontextualized way in which the subject is often taught. This study investigates how an interactive chemistry model, developed for a science communication exhibition, can influence high school students' perception and motivation to learn chemistry. Based on the Theory of Self-Determination, the chemistry model illustrates Advanced Oxidation Processes in a safe, interactive and accessible way. The exhibition was visited by 250 public high school students. Data was collected based on the responses of the participants who answered the Intrinsic Motivation Inventory questionnaire and took part in semi-structured interviews conducted as part of the study. The results obtained showed that the interactive chemistry model exerted a positive impact on the following intrinsic motivation factors: interest, perceived competence, effort, value, pressure/tension, and perceived choice. The science communication activity also stimulated the participants' interest in pursuing university education, reinforcing the role of non-formal education in helping overcome chemophobia.

Keywords

Science centres and museums; Popularization of science and technology; Bridging research; practice and teaching

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1 ▪ Introduction

Teaching and learning processes can occur in formal, non-formal, and informal settings, each with specific and complementary characteristics. Formal education takes place in school environments, primarily schools and universities, where instruction is guided by established curricula and educational guidelines [Gohn, 2006]. In contrast, informal education involves the sharing of knowledge through sociocultural interactions and occurs spontaneously [Livingstone, 2001]. Non-formal education occupies an intermediate space between the two, taking place outside traditional school settings but with pedagogical intent. It can be implemented in spaces such as museums, science centers, and fairs, promoting meaningful learning. According to Jacobucci [2008], this type of education enables interactive and contextualized approaches, valuing the active participation of individuals. In Brazil, museums are legally recognized as institutions with an educational role (Statute of Museums, Law 11,904/2009; Decree 8,124/2013) and are guided by the National Policy for Museum Education (PNEM), which sets out principles, audiences, and educational practices, including partnerships with schools [Instituto Brasileiro de Museus (Ibram), 2021]. Accordingly, we adopt a non-dichotomous framing: museums operate as hybrid spaces along a continuum between school and non-school contexts, in which activities may be formal (linked to curriculum/assessment) or non-formal (mediations, visits, workshops, projects) [de Oliveira & Bizerra, 2024; Instituto Brasileiro de Museus (Ibram), 2021; Johnson & Majewska, 2022].

In Brazil, persistent socioeconomic inequalities affect access to education, leisure, and culture, with direct impacts on the geographic distribution of museums. Recent data indicate that approximately 21% of municipalities have at least one museum, signaling a strong regional concentration of these institutions. Moreover, 31.4% of the population lives in municipalities without museums — a proportion higher among Black and brown (pardo) individuals and younger age groups [Ibram, "Museus em Numeros" Agência IBGE de Notícias, 2023]. Sector studies also point to a historical concentration in wealthier regions with stronger administrative capacity, with consequences for cultural participation and educational outcomes. In contrast, public perceptions of science remain positive and stated interest is high, but museum visitation is still limited — though growing — rising from 6.3% in 2019 to 11.5% in 2023 who reported visiting a science/technology museum in the previous 12 months [Centro de Gestão e Estudos Estratégicos (CGEE) & Ministério da Ciência, Tecnologia e Inovação (MCTI), 2019; Centro de Gestão e Estudos Estratégicos (CGEE), 2024]. This mismatch between interest and opportunities for access underscores the strategic role of out-of-school mediation in bringing science closer to society [Royal Society et al., 2024].

In this context, science exhibitions and centers play a formative role by offering interactive, situated experiences that activate affective and cognitive dimensions, fostering curiosity, belonging, and the construction of meaning around scientific knowledge [Bell et al., 2009; Childers et al., 2022; Jacobucci, 2008; Macdonald, 1998]. However, interactive chemistry modules face specific barriers compared to physics modules: recurring costs (operation and reagent replenishment), safety requirements and waste management, as well as the time needed for certain processes to become visible to the public [Steola & Kasseboehmer, 2018; Silberman et al., 2004]. Recent research points to mediation strategies that reduce these barriers: adopting low-threshold, low-maintenance manipulable artifacts; integrating author-created visual media (e.g., comic zines) to sustain engagement and conceptual understanding; and designing experiences that signal autonomy and competence to visitors [Cook & van Hest, 2024; Holme, 2024; Schlüter et al., 2022]. Within this horizon, the issue is no longer the supposed infeasibility of chemistry, but rather how to design exhibitions that meet safety and cost requirements without sacrificing meaningful interactivity.

However, the presence of chemistry in these environments remains limited. This is largely due to several challenges, such as the need for chemical reagents, specific glassware, and often a trained monitor, which makes including chemistry in interactive exhibitions more complex. Additionally, there is an ongoing concern about visitor safety, especially in activities aimed at school audiences [Silberman et al., 2004]. The absence of chemistry in non-formal education spaces contributes to reinforcing its negative image in society, often associated with risks, accidents, and difficult content [Schummer et al., 2007]. However, understanding chemical concepts is essential for exercising citizenship, as it enables the public to make more informed and critical decisions regarding issues involving science and technology. Therefore, increasing the presence of chemistry in these spaces not only means diversifying exhibition themes, but also rethinking mediation strategies, infrastructure, and more accessible language — creating innovative exhibition resources that allow the public to interact with chemical concepts in a safe and meaningful way.

In non-formal contexts, hands-on and collaborative practices expand opportunities for self-determined action and engagement [Childers et al., 2022; Classen, 2017; Rowe, 2002]. Among the various factors influencing student engagement in these contexts, intrinsic motivation stands out — defined as the individual's genuine interest in performing an activity for the pleasure and satisfaction it brings — which can be understood through the lens of Self-Determination Theory (SDT), proposed by Deci and Ryan [1985, pp. 232–242].

Self-Determination Theory (SDT) posits that human motivation is influenced by contextual and psychological factors, and it is strengthened when three basic psychological needs are satisfied: autonomy, competence, and relatedness [Niemiec & Ryan, 2009]. Activities that provide opportunities for positive feedback and foster a sense of autonomy contribute to the development of intrinsic motivation. In the school environment, intrinsic motivation emerges when students are curious to learn, persist in completing tasks even when they encounter difficulties, strive to accomplish them, and feel joy upon achieving success [Ryan & Deci, 2000]. Recent syntheses also map interest in out-of-school environments and call for studies that connect situational and enduring interest [Neher-Asylbekov & Wagner, 2022]. In addition, evidence indicates that scientific experiences outside school can affect knowledge, interest, and even academic choices years later [McDonald et al., 2023].

Childers et al. [2022] explored motivation for learning science in a science communication setting and their results showed that most participants reported acquiring knowledge and satisfying personal needs — factors considered motivational for participating in such activities. Additionally, interactions with other participants and scientific experts were also identified as motivational elements. Focusing on museums and science centers, studies by Wilson et al. [2017] and Di Franco et al. [2015] showed that visitors prefer replicas that can be physically manipulated rather than only observed. In other words, hands-on experiences offer more opportunities for self-determined action, which aligns with SDT principles [Ryan & Deci, 2017].

In chemistry education, author-created visual media, such as comic zines, have proven effective for engaging students and supporting conceptual understanding by lowering textual barriers and leveraging narrative, while also boosting engagement and a sense of competence [Cook & van Hest, 2024]. Applying Self-Determination Theory (SDT) helps explain why so many students show disinterest and difficulty engaging with the subject. As Jenkins and Nelson [2005] highlight, it is common for students to question the relevance of studying chemistry, revealing a disconnection between school content and students' lived realities. This lack of motivation is exacerbated when teaching is based solely on the memorization of formulas, with little room for experimentation, creativity or contextualization.

This study addresses a specific gap: the scarcity of investigations in chemistry that assess the motivational effects of low-barrier artifacts in exhibitions, articulating Self-Determination Theory (SDT) and a mixed-methods approach in the Brazilian context. Accordingly, it is essential to rethink pedagogical and exhibition practices, promoting more interactive and accessible environments capable of stimulating intrinsic motivation. This study examines the extent to which a public-engagement exhibition centered on an interactive model of advanced oxidation processes (AOP), designed for safe operation, immediate visual feedback, and accessible mediation, impacts high school students' intrinsic motivation. Specifically, we ask: (i) how the factors of the Intrinsic Motivation Inventory (IMI) (interest, value, perceived competence, pressure/tension, and perceived choice) manifest after the experience; and (ii) how students' perceptions, obtained through interviews, converge with or diverge from the quantitative findings.

2 ▪ Methodology

This study adopted a mixed-methods approach, combining both qualitative and quantitative techniques for data analysis, using instrument triangulation [Tobin & Fraser, 1998]. The research was guided by the principles of Self-Determination Theory [Deci & Ryan, 1985, pp. 232–242], with a focus on understanding the factors that influence students' intrinsic motivation in non-formal learning contexts.

The triangulation of instruments was conducted following the model of convergence and complementarity triangulation [Tobin & Fraser, 1998], aiming to integrate evidence from both quantitative and qualitative approaches in order to broaden the understanding of the observed phenomena. Initially, the results of the Intrinsic Motivation Inventory (IMI) questionnaire were analyzed by factor (interest, value, perceived competence, pressure, and perceived choice), allowing for the identification of general trends in intrinsic motivation among the participating schools. Subsequently, a thematic analysis of the interviews was carried out, in which categories such as interactivity, curiosity, daily life, and ability were examined in direct relation to the factors of Self-Determination Theory (autonomy, competence and relatedness). This stage made it possible to identify convergences (for example, between "interactivity" and perceived choice/autonomy), complementarities (such as reports of belonging and connection with the university, which were not captured in the questionnaire), and specific discrepancies (such as initial feelings of insecurity when handling the model, contrasting with high mean scores for competence). The integration of both data sets enabled a more robust interpretation of the motivational effects of the exhibition, strengthening the internal validity and theoretical coherence of the analysis.

2.1 ▪ *Development of the science communication exhibition*

Considering the importance of science communication for both society and the academic community, and with the aim of addressing the research question that guided this study, an exhibition was developed based on a university research group that investigates different processes for degrading organic compounds such as dyes, pharmaceuticals, and personal care products. Among these processes, the Advanced Oxidation Process (AOP) stands out, as it can transform organic compounds into less toxic substances and is considered an environmentally friendly technique. This context made it possible to explore and discuss, through science communication activities, concepts such as electrochemistry, oxidation for pollutant degradation, and radical reactions [Vasconcelos et al., 2016].

The model was designed as the central element of the activity and was later patented. Its main objective is to demonstrate chemical reactions based on the application of the Advanced Oxidation Process (AOP) in a visual, safe, and accessible manner for the public. The model was built using glassware and placed under an acrylic shield. After several tests, the optimal design was determined to be a wave-shaped configuration. Figure 1 shows a top view of the model, where it is possible to see two reagent input points, one water inlet for system cleaning, and one outlet for waste collection and disposal. Silica was added inside the glassware to improve the visualization of the chemical reaction. The dye used in the experiment was Reactive Blue 19, a synthetic dye widely used in the textile industry. It is water-soluble, has a bright blue hue and is resistant to light. The model was placed on a table, with signs encouraging visitors to interact with the equipment.

Figure 1. Assembled interactive model. The system simulates the degradation of dyes with hydrogen peroxide in a closed-loop pathway, activated by a button pressed by the visitor. The device is built from transparent acrylic, with labels identifying the reagents (dye, water, and hydrogen peroxide). The base features a sign saying "ATTENTION: Feel free to touch!", encouraging visitors to interact with the model. Source: Author's own work.

The science communication exhibition on chemistry was designed around the interactive model. It was hypothesized that displaying the model in isolation might negatively affect visitor motivation. However, when embedded in a visually appealing and contextualized setting, it could enhance public engagement. According to Almeida [2005], motivation is related not only to the content presented in the exhibitions, but also to the nature of the experience offered to the audience. Based on this, posters with explanatory texts and complementary objects were created to enrich the environment, attract visitors' attention, and reinforce the content addressed by the model (Figure 2).

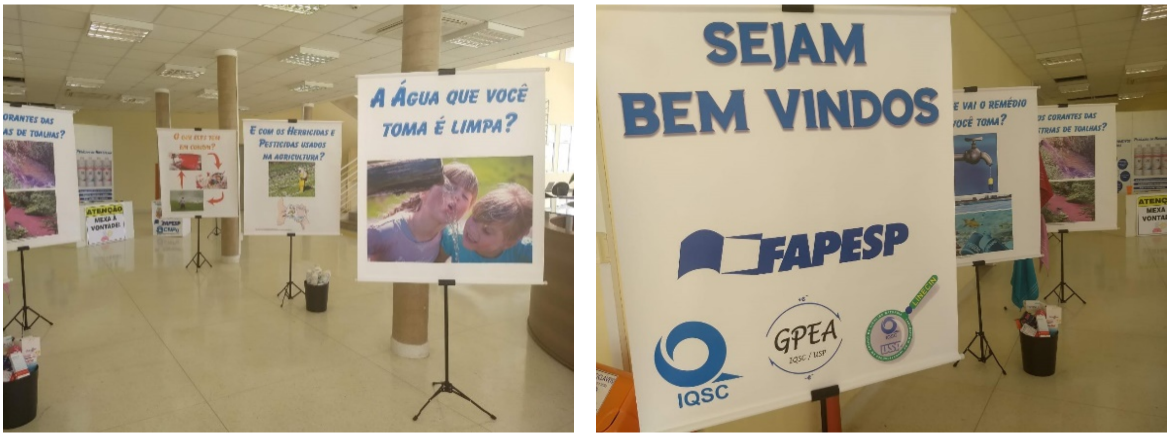

Figure 2. Exhibition assembled in the common area of the university library. The banners featured thought-provoking questions such as “Is the water you drink clean?” and “What if residues and pesticides were visible?”, aiming to engage the public with environmental and public health issues. At the entrance, a welcome banner displayed the logos of the partner institutions: FAPESP, IQSC-USP, GPEA and LINECIN, reinforcing the goal of bringing science closer to society through accessible language and visually appealing content. Source: Author’s own work.

2.2 ▪ *Participants*

The science communication exhibition was held in a common area of the library at a public university in Brazil. A total of 250 high school students participated in the activity, coming from six public schools located in the interior of São Paulo State (Table 1). The participants were between 15 and 18 years old and represented all three years of Brazilian high school education. Table 1 shows the number of students from each school who took part in the exhibition.

Table 1. Distribution of participating students by school.

School	Number of participants
A	51
B	43
C	37
D	54
E	30
F	35
Total	250

The six participating schools had diverse characteristics in terms of infrastructure, connection with the university and students’ expectations regarding access to higher education. All of them had a permanent Chemistry teacher, although not all had access to a laboratory. These differences were taken into account in the interpretation of the results.

School A is a medium-sized school with a full-time chemistry teacher and a laboratory. Although it has partnerships with university projects, students demonstrated low expectations of entering a public university.

School B also has a full-time chemistry teacher and is medium-sized, serving two neighborhoods in the city. It does not have a chemistry laboratory and receives few university projects; however, students have been increasingly encouraged to value public higher education.

School C shares similar characteristics with School B: it is medium-sized, has a full-time chemistry teacher, and receives few projects from the university. Many of its students attend technical courses in the afternoon and have been encouraged to pursue university education.

School D is a medium-sized school located in a more distant and economically disadvantaged neighborhood. It has a full-time chemistry teacher but no laboratory. Although it receives few university projects, students expressed positive expectations regarding access to higher education.

School E is relatively new compared to the others. It is medium-sized and serves a peripheral area with indicators of poverty. It has a full-time chemistry teacher but no laboratory. The school faces several social challenges, does not receive university projects, and students showed low expectations of entering a university.

School F is a medium-sized school that serves a neighborhood close to the university. It has a full-time chemistry teacher but lacks a laboratory. It participates in university projects, and students expressed interest in pursuing higher education.

Considering the social inequalities that characterize the Brazilian educational system, the participating schools were socioeconomically contextualized using official indicators. The institutions involved in this study are located in the municipalities of São Carlos and Ibaté, in the state of São Paulo, Brazil. According to the Brazilian Institute of Geography and Statistics (IBGE) Demographic Census, which is used to calculate the Municipal Human Development Index (HDI-M), São Carlos presents an HDI-M of 0.805, while Ibaté presents an HDI-M of 0.703. Although both municipalities are classified as having high human development, this difference indicates structural inequalities, particularly in terms of income, educational opportunities, and access to cultural and scientific facilities.

It is important to note that official IBGE data do not provide HDI indicators at the neighborhood or school level, which limits more detailed intra-urban socioeconomic analyses. Therefore, this contextualization is based on municipal-level indicators and aims solely to characterize the broader educational settings in which the participating schools are embedded, without establishing causal relationships between socioeconomic conditions and the study outcomes.

2.3 ▪ *Ethics and consent*

The project was approved by the Research Ethics Committee of the Faculty of Philosophy, Sciences, and Letters of Ribeirão Preto at the University of São Paulo, Brazil (FFCLRP-USP), under CAAE no. 79434917.2.00005407.

Before the activities were carried out, the Informed Consent Form (ICF) was presented to and signed by the students' parents or legal guardians, authorizing their participation in the exhibition and interviews. Assent Forms were also provided to the students, ensuring that their participation was voluntary and informed.

The participating schools issued institutional authorization for the visits and data collection. Throughout all stages of the research, specific ethical measures were adopted to ensure the well-being, privacy and safety of the participants, especially considering that they were children and adolescents. The interviews were conducted within the school environment, under the supervision of the responsible teachers, and all data were treated anonymously and confidentially.

2.4 ▪ *Instruments*

In the quantitative approach, the Intrinsic Motivation Inventory (IMI) developed by Deci and Ryan [2005] was used to assess participants' perceptions regarding a hands-on activity. The instrument consists of a Likert-type scale and includes statements distributed across six factors related to intrinsic motivation: interest, perceived competence, effort, value, pressure/tension, and perceived choice. For this study, the factors selected were interest, perceived competence, effort and value, as they were considered most appropriate for the voluntary and exploratory nature of the activity.

The version of the Intrinsic Motivation Inventory (IMI) used in this study was fully translated into Portuguese by a group of researchers with experience in Science Education, with the support of an English language professor, ensuring the semantic and conceptual equivalence of the items. During this process, some statements were adapted to the context of the museum exhibition and the interactive model, while preserving the original meaning of the instrument.
The questionnaire was reviewed by experts and pilot-tested with 15 students, which made it possible to identify and adjust potential ambiguities or difficult-to-understand terms. This stage ensured the cultural and linguistic appropriateness of the instrument, confirming its content validity for the Brazilian context. The internal consistency of the final version was verified using Cronbach's alpha coefficient ($\alpha = 0.79$), calculated from the responses of the 250 participants, indicating high reliability and coherence among the evaluated items, according to Toro-Arias et al. [2022].

In the qualitative approach, a semi-structured interview guide was used, a method widely employed in field research due to its ability to facilitate direct and flexible interaction between interviewer and interviewee. According to Kvale [2006], interviews are an effective technique for gathering information in social contexts, as they allow for the exploration of perceptions, meanings, and interpretations based on participants' experiences. In this study, the interview aimed to understand students' perceptions regarding the limitations and potential of the interactive model in relation to their motivation to learn chemistry.

In this study, the interview aimed to understand students' perceptions of the limitations and potential of the model with respect to their motivation for learning chemistry. The interview protocol was developed based on the principles of Self-Determination Theory [Deci & Ryan, 2005], which guides the analysis of factors that promote or hinder students' intrinsic motivation and engagement. To ensure the clarity, relevance, and theoretical validity of the questions, the instrument underwent expert validation by a panel of five researchers in Science Education, who provided suggestions and adjustments prior to it final administration.

Before the main data collection, a pilot study was conducted with a group of 15 students to identify and resolve possible issues of comprehension, ambiguity, or question order. This step allowed us to refine the instrument and ensure that the questions were properly understood, thereby increasing the reliability and consistency of the primary data collection.

2.5 ▪ *Patent submission*

The interactive model developed in this research was designed to safely and accessibly demonstrate real chemical phenomena, such as color change. The equipment allows autonomous observation of these phenomena without the need for technical mediation and was designed to be integrated into scientific exhibitions and educational spaces aimed at science communication. Its design sought to combine aesthetic, functional, and pedagogical aspects, ensuring the model's safety and replicability in different educational contexts. Due to its originality and applicability in teaching and science communication, the project resulted in the submission of a patent application to the National Institute of Industrial Property (INPI), with the aim of protecting the prototype's technical integrity and enabling its reproduction in other institutions.

2.6 ▪ *Data collection and analysis*

Initial contact with the schools was made by phone to present the research procedures, schedule university visits, and invite the institutions to participate in the study. The schools were selected based on prior contact with their principals, during which the purpose of the research and the invitation to participate voluntarily were presented. The selection of schools considered the diversity of geographic locations, including institutions situated in central areas, peripheral neighborhoods, and city districts, with the aim of obtaining a more heterogeneous and representative data sample from different school contexts. The institutions that expressed interest and availability were included in the visit schedule, which took place over two months. All students participated voluntarily, upon invitation and authorization from their respective schools.

Figure 3 presents the sequence of activities carried out by the students during their visit to the university. Upon arrival, students were divided into two groups: one group visited the science communication exhibition, while the other explored the university library. Afterwards, the groups switched activities. Following both the exhibition and the library visit, students were invited to complete the IMI questionnaire and then attended an interactive chemistry lecture.

The division of students into two groups served purely logistical purposes, aimed at avoiding overcrowding in the exhibition space and the library. This division did not affect data collection, as all groups followed the same route and performed the same activities in identical sequence.

The qualitative stage of the study was conducted through semi-structured interviews carried out at the schools, after the students' visits to the university. Students were invited to participate voluntarily, resulting in 44 recorded interviews, which were later transcribed for analysis.

For the quantitative analysis of the questionnaires, the Mean Rank of the responses was calculated for each item on the Likert scale. Some items in the instrument are marked with the letter "R," indicating reverse scoring — that is, the statements are negatively aligned with

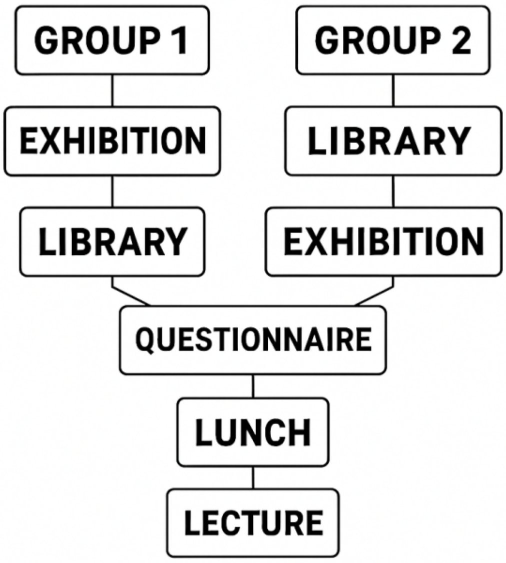

Figure 3. Flowchart of the students' visit to the university. Source: Author's own work.

the constructs of STD. The interviews were analyzed qualitatively using Thematic Analysis [Zhang & Kuo, 2001]. After transcribing the interviews, a full reading and categorization of the data were carried out, aiming to answer the research question initially posed.

The interviews were fully transcribed, preserving participants' expressions, pauses, and speaking time to maintain the authenticity and fidelity of their narratives. Subsequently, the transcripts were read and the data categorized, aiming not only to address the central research question but also to enable triangulation with the information obtained from the questionnaires. The categorization process was conducted in stages, including an initial reading, the generation of categories, the identification of themes, and a final review, in order to ensure coherence in the interpretation of the results.

3 ▪ Results

To understand the effects of the science communication activity on students' motivation, both the questionnaires and the semi-structured interviews were analyzed. The quantitative analysis was based on the calculation of the Mean Ranking (MR) of the scores assigned by participants to the items in the IMI questionnaire. Meanwhile, the qualitative analysis was conducted using Thematic Analysis of the semi-structured interviews to identify categories related to students' perceptions, feelings and interpretations of the activity they experienced.

3.1 ▪ *Intrinsic motivation inventory questionnaire*

The quantitative analysis was conducted through the calculation of the Mean Ranking (MR) of the responses, based on the scores attributed by the participants. The questionnaire was applied using a 5-point Likert scale, where responses ranged from 1 (strongly disagree) to 5 (strongly agree), with a midpoint value of 3. Table 2 presents the average scores per school for each factor item, allowing comparison among participating schools in terms of the intrinsic motivation stimulated by the experience.

Table 2 presents the Mean Rank (MR) results for each item of the IMI questionnaire by school, and the data show significant variations among participant groups. Overall, the averages indicate that the science communication activity was perceived positively, particularly in the factors of interest, value and perceived choice.

In the perceived competence factor, School C stands out with a mean score (4.28) on the statement “I think I did very well when using the model”, reflecting a positive perception of performance. In contrast, School D had the lowest score (2.22) on the item “After using the model for a while, I felt quite competent”, which may indicate difficulty in developing confidence in their own performance throughout the activity.

In the effort factor, although the direct items presented lower averages — suggesting the task was not perceived as demanding — the reverse-scored items, such as “I did not put much effort into using the model (R)”, showed higher scores, particularly in School C (4.25). This suggests that even if students did not find the task difficult, they were still actively engaged in the activity.

Regarding the pressure factor, all mean scores were below the midpoint, indicating a low perception of discomfort or obligation during the activity. The item “I felt pressured when using the model” received its highest value at School E (2.13), which still reflects a low sense of pressure. Meanwhile, the reverse-scored item “I did not feel nervous when using the model (R)” received its lowest value at School C (1.87), suggesting that some students from this school experienced initial nervousness.

The perceived choice factor assesses the sense of autonomy in participating in the proposed activities. The highest average was observed at School F (4.85) for the reverse-scored item “I felt as if I was forced to participate in this exhibition (R)”, indicating a greater perception of freedom. In contrast, School A showed the lowest values for this factor, indicating a reduced sense of choice or greater external influence.

The value factor, which reflects the internalization of the importance attributed to the activity, had its highest score at School B (4.62) for the statement “I believe this exhibition could be useful for me”, reinforcing the perceived educational relevance of the experience. The lowest mean score (3.11), found at School D, referred to the item “I think it is important to participate in this exhibition because it might make me more interested in Chemistry”, suggesting lower expectations regarding the impact of the activity on interest in the subject.

Finally, in the interest factor, mean scores were also mostly high. School C again stood out with a high score (4.90) for the item “I would describe this exhibition as very interesting”, indicating strong student engagement. On the other hand, the lowest value (3.22) was obtained at School E for the item “I thought this exhibition was quite enjoyable”, suggesting that although the exhibition was seen as relevant, not all students perceived it as a playful experience.

Based on the individual item data from the IMI questionnaire, it was possible to calculate the Mean Ranking for each intrinsic motivation factor by school, allowing for a more synthetic

Table 2. Mean Ranking by school of the items from the IMI questionnaire.

	Schools Afirmatives	A	B	C	D	E	F
Competence	I think I did very well when using the model.	3.25	4.23	4.28	3.13	3.50	3.31
	I think I did very well when using the model. compared to other people.	3.00	3.21	3.12	3.31	3.21	3.30
	After using the model for a while. I felt quite competent.	3.63	3.37	2.96	2.22	3.06	2.80
	I am satisfied with my performance when using the model.	3.61	4.10	4.26	3.48	3.86	3.40
	I did not do very well when using the model. (R)	4.46	4.00	4.05	4.25	2.96	3.51
Effort	I had to put in a lot of effort to use the model.	1.69	1.88	1.93	1.73	3.20	2.31
	I did not try very hard to use the model properly. (R)	3.91	4.37	4.13	3.61	3.46	3.40
	I had to dedicate myself a lot to use the model.	1.73	2.02	1.50	2.11	2.83	2.40
	It was important to me to do well when using the model.	2.68	3.86	4.25	2.61	3.10	2.82
	I did not put much effort into using the model. (R)	4.14	4.39	4.25	4.15	3.76	3.51
Pressure	I did not feel nervous when using the model. (R)	2.36	2.55	1.87	2.05	2.23	2.31
	I felt pressured when using the model.	1.50	1.30	1.47	1.44	2.13	1.11
	I felt very tense while participating in this exhibition.	1.94	1.53	1.31	4.62	1.66	4.54
	I was very relaxed while participating in this exhibition. (R)	2.47	1.81	3.51	3.20	2.96	3.17
	I felt anxious while participating in this exhibition.	2.63	3.46	3.54	2.40	2.76	2.91
Choice	I felt that participating in the exhibition was not my own choice. (R)	3.84	4.53	4.18	2.65	4.40	4.54
	I felt as if I was forced to participate in the exhibition. (R)	4.78	4.81	4.81	4.62	4.50	4.85
	I took part in the exhibition because I had no choice. (R)	4.21	4.76	4.63	3.20	4.70	4.77
	I participated in the exhibition activities because I was obligated to. (R)	4.52	5.00	5.00	4.54	4.86	4.94
	I participated in the exhibition activities because I wanted to.	4.26	4.69	4.86	2.40	4.43	4.71
Value	I believe this exhibition could be useful for me.	3.57	4.62	4.36	4.11	4.13	4.22
	I think participating in this exhibition is helpful for wanting to learn Chemistry.	4.15	4.60	4.45	3.62	4.06	4.45
	I think it is important to participate in this exhibition because it might make me more interested in Chemistry.	3.84	4.53	4.13	3.11	4.13	3.97
	I would be willing to participate in the exhibition again because it is useful for me.	3.47	4.58	4.27	3.22	4.06	4.14
	I think participating in this exhibition could help me enjoy Chemistry more.	3.57	4.60	4.09	3.28	3.96	4.00
Interest	I had a lot of fun participating in this exhibition.	4.00	4.81	4.68	3.68	4.76	4.54
	It was fun to participate in this exhibition.	4.15	4.72	4.68	3.91	4.76	4.65
	I thought this exhibition was boring. (R)	4.21	4.79	4.86	3.91	4.80	4.51
	I would describe this exhibition as very interesting.	3.84	4.79	4.90	3.65	4.20	4.14
	I thought this exhibition was quite enjoyable.	4.05	4.67	4.40	3.22	4.53	4.02
(R) indicates reverse-scored statements							

and comparative view. Table 3 presents the RM values for the factors of perceived competence, effort, pressure, choice, value, and interest for each of the participating schools.

Table 3. Mean Ranking of intrinsic motivation factors by school.

Factor	School A	School B	School C	School D	School E	School F
Competence	3.58	3.78	3.68	3.06	3.29	3.26
Effort	2.63	2.92	3.12	2.77	3.05	2.99
Pressure	1.93	2.02	2.12	2.03	2.19	2.21
Choice	4.00	4.21	4.44	4.24	4.28	4.46
Value	3.85	4.21	4.4	3.87	4.10	4.14
Interest	4.05	4.50	4.67	4.32	4.22	4.32

Table 3 shows the Mean Ranking (MR) analysis for each factor by school, allowing for the identification of relevant patterns in how students perceived and engaged with the science communication activity as a whole, including both the exhibition and the model.

The interest factor presented the highest averages among all evaluated factors, with School C (4.67) and School B (4.50) standing out. These results indicate that the activity was widely perceived as engaging and capable of sparking students' curiosity.

The pressure factor showed the lowest scores among all factors, with values ranging (1.93 to 2.21). These results are positive, as they indicate that students experienced the activity with a low level of stress or discomfort, thus promoting a welcoming learning environment.

Overall, Schools B, C and F had the highest overall means, demonstrating a greater impact of the activity in terms of intrinsic motivation. School D, on the other hand, recorded the lowest scores across several factors, which may indicate students' limited familiarity with science communication experiences. The data reinforce the importance of well-designed interactive initiatives, particularly in educational contexts with limited access to such activities.

3.2 ▪ *Semi-structured interview*

During data collection, a semi-structured interview was conducted with the students in order to complement the quantitative results and identify possible convergences and divergences in relation to the responses obtained from the questionnaires. The qualitative analysis provided a deeper understanding of the participants' perceptions regarding the experience. For this study, only the interview questions in which students mentioned or made direct reference to the model and the exhibition were selected, in order to focus the analysis on the most relevant aspects related to intrinsic motivation in the context of science communication.

Table 4 presents the categories extracted from the interviews and the frequency of student responses to the question: "What were the positive aspects of the exhibition?"

As shown in Table 4, in response to the question *"What were the positive aspects of the exhibition?"*, five main categories emerged. The data revealed an overall positive evaluation, with emphasis on aspects related to engagement, perceived relevance, and connections to everyday life.

Table 4. Categorization of responses to the question "What were the positive aspects of the exhibition?".

Category	Frequency	Example
Interactivity	47.7% (n=21)	"I really liked how you let the student…the student on their own pick up and interact without someone constantly explaining, you know? Letting us explore, read, and understand first…it was interactive." (Interview 15, student from School A)
Interesting	100% (n=44)	"I found it very interesting for our knowledge…I would've never imagined what happens in there, you know? It was really interesting how you showed the whole cleaning process…things that help in life." (Interview 25, student from School B)
Curiosity	25% (n=11)	"I got really curious…what was that blue liquid…to understand how the model worked…I thought it was cool…" (Interview 44, student from School F)
Chemical Reactions	25% (n=11)	"The reactions there…we never do them at school…the teacher doesn't take us to the lab because we don't have one…so yeah, I thought the chemical reactions were cool…" (Interview 29, student from School E)
Everyday Life	20% (n=9)	"Ah…I felt like I could interact there…like something from everyday life…part of the daily routine…" (Interview 22, student from School D)

The category "interesting" was unanimously mentioned by all interviewees (100%), indicating that the activity was perceived as meaningful and engaging. Interactivity was also highly valued, mentioned by 47.7% of participants, suggesting they appreciated the opportunity to explore the model autonomously, without direct mediation, an element that may be linked to the perception of choice, one of the core components of intrinsic motivation.

The categories curiosity and chemical reactions were each cited by 25% of students. Curiosity mainly stemmed from the desire to understand how the model worked and the chemical processes involved. Mentions of chemical reactions reflected appreciation for the experimental aspect, typically absent from students' regular school routines, reinforcing the potential of exhibitions to complement the limitations of formal education.

Finally, the category "everyday life" was mentioned by 20% of the interviewees, indicating that some students were able to relate the experience to practical day-to-day situations, thus strengthening the connection between science and real life.

Table 5 shows the categorization and frequency with which these categories appeared in the students' responses to the question "How did you feel when interacting with the model?"

The data in Table 5 help to understand how students assessed their own performance and the complexity of the activity. The participants' statements reflect perceptions related to self-efficacy, simplicity, and interest; factors directly aligned with the concepts of intrinsic motivation, perceived competence, interest, and effort.

The category sense of capability was mentioned by 25% of interviewees, revealing that although some initially felt insecure, they began to feel capable once they understood how

Table 5. Frequency of responses to the question: "How did you feel when interacting with the model?".

Category	Frequency	Example
Sense of Capability	25% (n=11)	"How did I feel using the model? Ah…I found it interesting…it took me a while to understand…but when I figured out how it worked, I felt capable…the guys there were pressing it…I saw it wasn't hard…you just had to press the green thing and it turned on…" (Interview 40, student from School F)
Interesting	18% (n=8)	"Ah, the model? Interesting…seeing the chemistry…those reactions and all…" (Interview 27, student from School D)
I Did Well	25% (n=11)	"I felt normal…I did fine, right? It was just pressing that button and it turned on…no mystery to it…" (Interview 9, student from School A)
Ease	20% (n=9)	"There was no secret…it was the easiest thing…just press that green clover and it worked…but I found it interesting." (Interview 33, student from School E)

the model worked. The "I did well" category also appeared in 25% of responses, often associated with a sense of calmness while performing the task and a self-assessment of satisfactory performance, even when engaging in an activity that is unusual in their school routine.

The ease category was cited by 20% of participants, who described the experience as simple and straightforward. The statement from Interview 33 (School E) shows that even though the task was considered technically easy, this did not prevent it from being perceived as interesting, suggesting that engagement is not necessarily tied to task complexity.

The interesting category, mentioned by 18% of students in this context, complements the others by showing that the model remained attractive even for those who judged it to be easy or not particularly challenging.

Table 6 presents the students' responses to the question "Did visiting the exhibition spark any interest in you? If so, what kind?", highlighting what aspects of the experience were most engaging.

Table 6. Frequency of responses to the question: "Did visiting the exhibition spark any interest in you? If so, what kind?".

Category	Frequency	Example
University	47.7% (n=21)	"I've always been curious about what a university is like, but I never had the chance to visit one…now that I've seen it, I feel motivated to go to college." (Interview 41, School F)
Knowledge	25% (n=11)	"Yes…I wanted to learn more…to do more things like what I did there…I liked it…I even got home and started researching more about the subject discussed in the exhibition." (Interview 7, School A)
Chemistry	20% (n=9)	"I already liked Chemistry a lot, and now I'm even more interested in studying it." (Interview 14, School B)

Regarding the question “Did visiting the exhibition spark any interest in you? Which one?”, Table 6 presents three categories: university, knowledge, and chemistry. These categories reflect students’ reactions in relation to their educational aspirations, search for further information, and interest in science, showing that participation in the science outreach activity had an impact beyond the moment of the visit.

The university category was the most frequently mentioned, appearing in 47.7% of the responses. Students’ statements during the interviews revealed that visiting the university sparked curiosity, a sense of belonging, and projections about their academic future. Even students who had never previously visited a university expressed interest in learning more and even pursuing higher education. This finding is particularly relevant given the participants’ background in public schools, which are often distanced from scientific activities due to structural and socioeconomic barriers.

The knowledge category, mentioned by 25% of students, refers to the value placed on learning as a result of participating in the exhibition. Students reported that the experience sparked curiosity and a desire to explore the content further, including independent research on the topics after the visit. This behavior suggests a type of engagement that goes beyond momentary motivation, indicating a process of internalizing interest.

Finally, the chemistry category, mentioned by 20% of the interviewees, shows that the science outreach activity had a direct impact on students’ interest in chemistry. Students who already had an affinity for the subject reported a reinforcement of their interest, and some expressed a desire to take courses or deepen their studies. This demonstrates the potential of science communication initiatives to bridge the gap between academic content and students’ personal interests.

4 ▪ Discussion

This study contributes to the literature by examining, in the Brazilian context, the motivational effects of a low-barrier artifact in chemistry, combining quantitative and qualitative data. The triangulation indicates convergence between the IMI and interview accounts: mentions of curiosity and “being able to tinker” align with elevated levels of interest/value. Conversely, initial hesitations or operational doubts observed in interviews suggest refining scaffolding (brief guides, clear goals) and increasing hands-on time to maximize perceived competence. The exhibition analyzed maintains safety, low maintenance, and immediate feedback, aligning these features with SDT. By evidencing increases in interest and value, signs of developing competence, and low perceived pressure, the exhibition supported autonomy (through the possibility of exploring the model independently), competence (via clear operational feedback), and relatedness (through collaborative interaction and a welcoming university environment). In this sense, it offers a concrete pathway for integrating chemistry into non-formal educational settings.

The factors evaluated in the Intrinsic Motivation Inventory (IMI) are directly related to the three basic psychological needs proposed by SDT: autonomy, competence, and relatedness. Autonomy is primarily reflected in the perceived choice factor, which expresses how freely students felt to interact with the exhibition. The pressure factor is also related to autonomy but represents a negative indicator of intrinsic motivation within the questionnaire. Competence, in turn, reflects the students’ sense of efficacy in performing the proposed task.

The factors of interest, value, and effort are more broadly connected to both competence and autonomy, as they involve spontaneous engagement with the task, recognition of its importance and willingness to voluntarily invest effort.

Finally, although the questionnaire does not include a specific factor for relatedness, the interviews revealed aspects of this domain, such as feelings of connection with the university, collaboration with peers, and recognition of scientists' concern with environmental issues [de Oliveira & Bizerra, 2024].

Among these dimensions, interest emerged as the most salient across both instruments. The interest factor was highlighted both in the questionnaires and in the interviews, indicating that students spontaneously engaged with the activity. According to Deci and Ryan [2000], interest is one of the core components of intrinsic motivation, representing the experience of pleasure and involvement in performing a task. In this sense, Appel et al. [2010] point out that an individual's interest and ability are linked to the perception of autonomy, as it is through autonomy that one feels free to make personal choices and decisions. However, as Ainley and Ainley [2011] caution, interest can also be affected by previous experiences of failure, which may lead to a long-term decline in engagement, especially when students feel incapable of performing the proposed tasks.

Jacobucci [2008] emphasizes that exhibitions in non-formal education spaces should be organized in ways that capture the visitor's attention and keep them captivated by the content presented — a principle that appears to have been achieved in this study. This can be confirmed by participants' comments, such as the statement from Interview 15 (School A): "I found the exhibition interesting because it was about environmental topics... you know, those towels on display... it's good to know that there are people studying solutions for the environment." (Interview 15, School A).

The statement above reveals that the students' interest stemmed not only from the format of the activity but also from its content, which was closely related to their everyday concerns. In addition, the practical, visual, and accessible approach of the science communication proposal contributed to the creation of a more engaging and meaningful learning environment.

Although interest strongly shaped students' engagement, SDT suggests that motivation is sustained only when learners also feel competent in the activity [Deci & Ryan, 2000]. Thus, examining perceived competence helps clarify how students interpreted their own performance while interacting with the model.

Regarding the perceived competence factor, it was observed that most students felt capable of interacting with the model and understanding its functioning, even when they initially reported fear or insecurity. This aspect is essential for strengthening intrinsic motivation, as SDT establishes that feeling competent fosters engagement and the internalization of learning.

The statement "After handling the model for a while, I felt quite competent" received the lowest score within the competence factor, especially at School D, which had a score well below the midpoint (2.22), possibly indicating a weakened perception of competence. According to Schunk [1991], perceived competence, also referred to as self-efficacy, is linked to an individual's belief in their ability to successfully complete tasks, and it tends to be reinforced through positive experiences, leading to greater engagement and persistence.

Another relevant finding was observed in the statement "I didn't do very well when handling the model (R)," where the highest score was recorded at School A (4.46). Since this is a reverse-coded item, the result indicates that students did not feel competent when interacting with the model, which can be explained by several factors. According to Johnstone [1999], students in traditional teaching environments with no laboratory practices are often conditioned to view chemistry as a dangerous science, reinforcing feelings of fear and passivity. This sense of initial insecurity is echoed in Interview 30 (School E):

> "Ah, at first I didn't understand... I was afraid to touch it and break something, or get shocked when pressing the button... I didn't do very well... I don't know... I was kind of confused too... then some friends went and interacted with it and I started to see it wasn't that hard... I began to understand that the liquids entered through the tubes... I didn't do very well... but I understood... " (Interview 30, student from School E).

From this, it is evident that observing peers interacting with the model served as a support mechanism to overcome insecurity, aligning with Sheldon and Bettencourt's [2002] assertion that social relationships play a strong role in influencing individuals' self-confidence in learning contexts. In this perspective, the traditional classroom structure often places students in a passive role, limiting their autonomy [Reeve, 2009; Ryan & Deci, 2000]. This may explain why many students felt insecure when first engaging with the model, despite later reporting satisfaction with the learning gained from the visit.

While developing a sense of competence was central to students' engagement with the activity, SDT highlights that competence alone is not sufficient to sustain intrinsic motivation. Learners must also perceive that their actions are self-endorsed and freely chosen [Deci & Ryan, 2000]. In this sense, examining perceived choice and pressure helps clarify the extent to which students experienced autonomy during their interaction with the exhibition.

Autonomy is directly related to the perceived choice factor. Most students reported feeling comfortable participating in the activity, with a sense of freedom to interact with the elements of the exhibition. In the Brazilian context, the factor of choice is also linked to cultural habits surrounding visits to museums and science centers. According to Falk et al. [2004], unlike European and North American audiences, who have a consolidated habit of visiting these spaces as part of their cultural and leisure practices, in other contexts such as Latin America, people tend to visit them only in tourist or school settings, often encouraged by tour guides or teachers.

While perceived choice and freedom to explore the exhibition were central to students' sense of autonomy, SDT emphasizes that motivation is also shaped by social connections and feelings of belonging [Deci & Ryan, 2000]. Autonomy-supportive environments do not exclude social interaction; rather, they often create conditions in which collaboration, mutual support, and identification with a learning community can emerge. In this regard, examining indicators of relatedness helps clarify how interpersonal dynamics and contact with the university environment contributed to students' motivational experiences.

During the interviews, students were asked about their previous experiences with science exhibitions or museum visits. Of the 44 interviews analysed, only seven students reported having visited museums before, and three of those visits occurred through school field trips. These findings show that, for many students, the exhibition represented their first contact with this type of space, reinforcing the importance of science communication initiatives that bring science beyond major urban centres.

Although the questionnaire did not include a specific factor related to belonging, this element emerged in the interviews. Participation in the exhibition sparked curiosity about university life, promoting a connection between school and university, and a growing interest in continuing their education. This connection not only fosters a sense of belonging but also broadens the students' perception of possible futures involving higher education. Archer et al. [2013] highlight that exposure to scientific and academic environments can act as a guiding influence in the trajectories of students from basic education, particularly in populations historically distanced from these spaces.

Peer collaboration was also an important aspect, revealing bonds of support and interpersonal trust that reinforce the feeling of group belonging. Interpersonal relationships are essential for genuine engagement in learning activities, especially among adolescents [Baumeister & Leary, 1995; Niemiec & Ryan, 2009]. Additionally, the sense of belonging was evident in students' comments highlighting the importance of researchers working to find solutions to environmental problems.

These findings indicate that the exhibition did more than support individual engagement with scientific content: it also fostered relational experiences that strengthened students' sense of belonging. Feelings of connection with peers, interaction with researchers and contact with the university environment contributed to students' perceptions of being welcomed into a space traditionally perceived as distant or inaccessible. Within the framework of SDT, such experiences of relatedness are central to sustaining motivation, particularly among adolescents who may lack prior identification with academic or scientific institutions.

Although municipal indicators provide an important socioeconomic reference, educational inequalities in the Brazilian context are not restricted to differences between municipalities. Within São Carlos, often referred to as the "city of doctors" due to its high concentration of researchers affiliated with public universities, marked disparities exist between central and peripheral schools. Studies indicate that schools located in central areas tend to offer students greater exposure to academic culture, scientific activities, and university-related initiatives, whereas peripheral schools often face limited access to such opportunities and are more frequently associated with narratives of learning difficulties and reduced academic expectations [Silva & Kasseboehmer, 2023].

This spatial stratification of education is particularly evident in differentiated access to public universities. Central schools tend to establish more frequent and systematic interactions with universities through visits, extension projects, and institutional partnerships, while peripheral schools remain more distant from these spaces, both geographically and symbolically. Although São Carlos has one PhD holder for approximately every 200 inhabitants and hosts highly productive public universities, this scientific capital is unevenly distributed across the urban territory.

Students from peripheral neighbourhoods face not only socioeconomic barriers but also limited familiarity with pathways to access public universities, including admission processes and academic opportunities. This constitutes a subtle yet significant form of exclusion from the scientific and cultural capital concentrated in the city. Without such contextualization, differences observed in students' motivation, confidence and engagement could be misinterpreted as individual or school-level effects rather than reflections of broader territorial and socioeconomic inequalities.

Thus, the interpretation of the findings of this study must consider these contextual factors, as geographic proximity to a university does not necessarily translate into symbolic proximity or effective access to its resources. These structural conditions shape students' prior experiences with science, their expectations regarding higher education, and their perceived competence during non-formal scientific activities.

When interpreted in light of these territorial and socioeconomic conditions, the findings of this study gain greater explanatory depth and avoid overgeneralization. Rather than attributing differences in motivation solely to individual or school-level characteristics, this perspective highlights how structural inequalities shape students' prior experiences with science, their expectations regarding higher education, and their sense of belonging in academic spaces. At the same time, the positive motivational responses observed across schools suggest that well-designed non-formal experiences can partially mitigate these asymmetries by offering accessible, autonomy-supportive, and relationally rich encounters with scientific knowledge.

The results align with evidence that hands-on experiences and accessible mediation foster interest and engagement [Bell et al., 2009; Childers et al., 2022]. They also extend the findings of McDonald et al. [2023] by indicating that features such as autonomy and perceived relevance can sustain effects beyond the visit, even though our focus is on high school students. In the domain of chemistry, they reinforce that historical barriers (cost, safety, reaction time) can be mitigated through low-maintenance artifacts and author-created visual media [Cook & van Hest, 2024; Holme, 2024].

4.1 ▪ *Limitations*

This study has some limitations. First, the cross-sectional design and the absence of follow-up prevent inferences about the maintenance of motivational effects over time. Second, the sample was obtained in a single context (a university exhibition) and involved schools with specific characteristics, which restricts the generalizability of the findings. Additionally, socioeconomic differences between and within municipalities could only be addressed at a municipal level, as official statistics do not provide school- or neighbourhood-level indicators, limiting more fine-grained analyses of intra-urban inequalities. Third, the indicators used are mostly self-reports (IMI), which are subject to social desirability bias and a novelty effect; although we triangulated with interviews, we did not collect systematic behavioural metrics, for example, visitors' dwell time at the exhibition.

As directions for future work, we suggest longitudinal follow-ups at 3–6 months and 12 months (e.g., interest, academic intentions, return visits to the exhibition); replications in different regions, including museums/itinerant centres and other age groups; and psychometric analyses of the IMI by factor (α/ω; EFA/CFA) with tests of invariance across schools.

5 ▪ Conclusion

The present study aimed to investigate how a science outreach exhibition, cantered around an interactive chemistry model, could contribute to motivating high school students to learn chemistry. Data analysis, based on the Self-Determination Theory, indicated that participants demonstrated high levels of intrinsic motivation, with emphasis on the factors of interest, perceived competence, and value attributed to the activity. These results highlight the potential of science communication exhibitions in non-formal education settings as effective strategies to foster engagement and learning in chemistry.

The findings of this study are consistent with existing literature, particularly with research emphasizing the importance of meaningful and contextualized experiences in science education. By offering a more playful, participatory, and student-centred environment, the exhibition helped reduce the negative perception of chemistry and brought students closer to the university setting, especially those from communities with limited access to scientific spaces. These findings reinforce the importance of science communication actions as to democratize knowledge.

Finally, reflecting on the role of motivation in non-formal education settings allows for a deeper understanding of how psychological factors, such as the sense of autonomy, competence, and belonging, influence individuals' engagement with knowledge, even if motivation alone is not sufficient. When combined with well-structured educational practices that are sensitive to students' realities, motivation can significantly enhance interest and learning. In the activities developed in this study, it was observed that freedom of choice and interactivity contributed to strengthening intrinsic motivation, even in the face of initial challenges such as fear of manipulating the model. These findings underscore the value of motivation as a mediator in science education within non-formal environments and suggest that its potential should be continuously and intentionally explored to promote meaningful and transformative experiences.

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References

Agência IBGE de Notícias. (2023, December 1). *Região Norte tem menor acesso a cinemas, teatros e museus*. Instituto Brasileiro de Geografia e Estatística (IBGE). Retrieved September 30, 2025, from https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/38502-regiao-norte-tem-menor-acesso-a-cinemas-teatros-e-museus

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: the contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology*, *36*, 4–12. https://doi.org/10.1016/j.cedpsych.2010.08.001

Almeida, A. M. (2005). O contexto do visitante na experiência museal: semelhanças e diferenças entre museus de ciência e de arte. *História, Ciências, Saúde-Manguinhos*, *12*, 31–53. https://doi.org/10.1590/s0104-59702005000400003

Appel, M. S., Wendt, G. W., & Argimon, I. I. L. (2010). A teoria da autodeterminação e as influências socioculturais sobre a identidade. *Psicologia em Revista*, *16*, 351–369. https://pepsic.bvsalud.org/scielo.php?script=sci_arttext&pid=S1677-11682010000200008

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2013). 'Not girly, not sexy, not glamorous': primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*, *21*, 171–194. https://doi.org/10.1080/14681366.2012.748676

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*, 497–529. https://doi.org/10.1037/0033-2909.117.3.497

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. (2009). *Learning science in informal environments: people, places and pursuits*. National Academies Press. https://doi.org/10.17226/12190

Centro de Gestão e Estudos Estratégicos (CGEE). (2024). *Percepção pública da C&T no Brasil — 2023. Resumo executivo*. Brasília, DF, Brazil, CGEE. Retrieved September 30, 2025, from https://static.poder360.com.br/2024/05/percepcao-ciencia-tecnologia-15mai2024.pdf

Centro de Gestão e Estudos Estratégicos (CGEE) & Ministério da Ciência, Tecnologia e Inovação (MCTI). (2019). *Percepção pública da ciência e tecnologia no Brasil — 2019*. Retrieved September 30, 2025, from https://cdi.mecon.gob.ar/bases/docelec/az4487.pdf

Childers, G., Governor, D., Osmond, D., & Britton, S. (2022). Science cafés: exploring adults' motivation to learn science in a community space. *Research in Science Education*, *52*, 1055–1073. https://doi.org/10.1007/s11165-020-09982-2

Classen, C. (2017). Introduction. In C. Classen (Ed.), *The museum of the senses: experiencing art and collections* (pp. 1–7). Bloomsbury Publishing Plc. https://doi.org/10.5040/9781474252454

Cook, A. B., & van Hest, J. C. M. (2024). Comic zines as tools for chemistry education and engaging students. *Journal of Chemical Education*, *102*, 929–934. https://doi.org/10.1021/acs.jchemed.4c00972

de Oliveira, B. H., & Bizerra, A. F. (2024). Social participation in science museums: a concept under construction. *Science Education*, *108*, 123–152. https://doi.org/10.1002/sce.21829

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Plenum Press. https://doi.org/10.1007/978-1-4899-2271-7

Deci, E. L., & Ryan, R. M. (2005). Intrinsic Motivation Inventory (IMI). *University of Rochester*. https://selfdeterminationtheory.org/intrinsic-motivation-inventory/

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry*, *11*, 227–268. https://doi.org/10.1207/s15327965pli1104_01

Di Franco, P. D. G., Camporesi, C., Galeazzi, F., & Kallmann, M. (2015). 3D printing and immersive visualization for improved perception of ancient artifacts. *Presence: Teleoperators and Virtual Environments*, *24*, 243–264. https://doi.org/10.1162/pres_a_00229

Falk, J. H., Scott, C., Dierking, L., Rennie, L., & Jones, M. C. (2004). Interactives and visitor learning. *Curator: The Museum Journal*, *47*, 171–198. https://doi.org/10.1111/j.2151-6952.2004.tb00116.x

Gohn, M. d. G. (2006). Educação não-formal, participação da sociedade civil e estruturas colegiadas nas escolas. *Ensaio: Avaliação e Políticas Públicas em Educação*, *14*, 27–38. https://doi.org/10.1590/s0104-40362006000100003

Holme, T. (2024). 101 years of chemistry everywhere: outreach and chemical education. *Journal of Chemical Education*, *101*, 1779–1781. https://doi.org/10.1021/acs.jchemed.4c00436

Instituto Brasileiro de Museus (Ibram). (2021). *Política Nacional de Educação Museal (PNEM)* [Revision 2021; originally published in 2017]. Retrieved September 30, 2025, from https://www.gov.br/museus/pt-br/assuntos/politicas-do-setor-museal/politica-nacional-de-educacao-museal-pnem

Jacobucci, D. F. C. (2008). Contribuições dos espaços não-formais de educação para a formação da cultura científica. *Revista Em Extensão*, *7*, 55–66. https://doi.org/10.14393/ree-v7n12008-20390

Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: students' attitudes towards secondary school science in England. *Research in Science & Technological Education*, *23*, 41–57. https://doi.org/10.1080/02635140500068435

Johnson, M., & Majewska, D. (2022). *Formal, non-formal and informal learning: what are they and how can we research them?* [Research report]. Cambridge University Press & Assessment.

Johnstone, A. H. (1999). The nature of chemistry. *Education in Chemistry*, *36*, 45–47.

Kvale, S. (2006). Dominance through interviews and dialogues. *Qualitative Inquiry*, *12*, 480–500. https://doi.org/10.1177/1077800406286235

Livingstone, D. W. (2001). *Adults' informal learning: definitions, findings, gaps and future research*.

Macdonald, S. (Ed.). (1998). *The politics of display: museums, science, culture*. Psychology Press. https://doi.org/10.4324/9780203838600

McDonald, S., Beer, S., & Cragg, L. (2023). The impact of out-of-school science activities for primary school children on science knowledge, interest and later academic choices: an evaluation study. *Research for All*, *7*. https://doi.org/10.14324/rfa.07.1.20

Neher-Asylbekov, S., & Wagner, I. (2022). Effects of out-of-school STEM learning environments on student interest: a critical systematic literature review. *Journal for STEM Education Research*, *6*, 1–44. https://doi.org/10.1007/s41979-022-00080-8

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence and relatedness in the classroom: applying self-determination theory to educational practice. *Theory and Research in Education*, *7*, 133–144. https://doi.org/10.1177/1477878509104318

Reeve, J. M. (2009). Why teachers adopt a controlling motivating style toward students and how they can become more autonomy supportive. *Educational Psychologist*, *44*, 159–175. https://doi.org/10.1080/00461520903028990

Rowe, S. (2002). The role of objects in active, distributed meaning-making. In *Perspectives on object-centered learning in museums* (pp. 19–35).

Royal Society, Engineering U.K. & Verian. (2024). *Science education tracker 2023*. Retrieved September 30, 2025, from https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology*, *25*, 54–67. https://doi.org/10.1006/ceps.1999.1020

Ryan, R. M., & Deci, E. L. (2017). Psychological needs. Varied concepts and a preliminary description of SDT's approach. In *Self-determination theory: basic psychological needs in motivation, development, and wellness* (pp. 80–101). Guilford Press. https://doi.org/10.1521/978.14625/28806

Schlüter, B., Strippel, C. G., Lewalter, D., & Sommer, K. (2022). Everybody wants to experiment: assessing motivation to participate in a chemistry family learning course. *Journal of Chemical Education*, *99*, 3133–3142. https://doi.org/10.1021/acs.jchemed.2c00321

Schummer, J., Bensaude-Vincent, B., & Van Tiggelen, B. (Eds.). (2007). *The public image of chemistry*. World Scientific. https://doi.org/10.1142/6636

Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist*, *26*, 207–231. https://doi.org/10.1080/00461520.1991.9653133

Sheldon, K. M., & Bettencourt, B. A. (2002). Psychological need-satisfaction and subjective well-being within social groups. *British Journal of Social Psychology*, *41*, 25–38. https://doi.org/10.1348/014466602165036

Silberman, R. G., Trautmann, C., & Merkel, S. M. (2004). Chemistry at a science museum. *Journal of Chemical Education*, *81*, 51. https://doi.org/10.1021/ed081p51

Silva, M. S. B., & Kasseboehmer, A. C. (2023). Comparative analysis of chemistry teaching in city center and suburban public schools in Brazil: how school reputation and social profile influence chemistry teaching and high school students' performance in science. *Cultural Studies of Science Education*, *18*, 985–1019. https://doi.org/10.1007/s11422-023-10192-1

Steola, A. C. D. S., & Kasseboehmer, A. C. (2018). O espaço da química nos centros e museus de ciências brasileiros. *Química Nova*, *4141*, 1072–1082. https://doi.org/10.21577/0100-4042.20170248

Tobin, K., & Fraser, B. J. (1998). Qualitative and quantitative landscapes of classroom learning environments. In *International Handbook of Science Education* (pp. 623–640). Springer Netherlands. https://doi.org/10.1007/978-94-011-4940-2_36

Toro-Arias, J., Ruiz-Palomino, P., & del Pilar Rodríguez-Córdoba, M. (2022). Measuring ethical organizational culture: validation of the spanish version of the shortened corporate ethical virtues model. *Journal of Business Ethics*, *176*, 551–574. https://doi.org/10.1007/s10551-020-04687-y

Vasconcelos, V. M., Souza, F. d. L., Guaraldo, T. T., Migliorini, F. L., Baldan, M. R., Ferreira, N. G., & Lanza, M. R. d. V. (2016). Electrochemical oxidation of reactive black 5 and blue 19 dyes using a non commercial boron-doped diamond electrode. *Química Nova*, *39*, 1051–1058. https://doi.org/10.5935/0100-4042.20160117

Wilson, P. F., Stott, J., Warnett, J. M., Attridge, A., Smith, M. P., & Williams, M. A. (2017). Evaluation of touchable 3D-printed replicas in museums. *Curator: The Museum Journal*, *60*, 445–465. https://doi.org/10.1111/cura.12244

Zhang, T., & Kuo, C.-C. J. (2001). Audio content analysis for online audiovisual data segmentation and classification. *IEEE Transactions on Speech and Audio Processing*, *9*, 441–457. https://doi.org/10.1109/89.917689

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