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Exploring how high school students experience intrinsically motivating elements in a science communication lecture on research in chemistry

Recto running head : INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, PART B

Verso running head : F. C. SENTANIN ET AL.

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ABSTRACT

Motivation is a key aspect of learning, and the degree of motivation is primarily dependent on the environment in which the learning process takes place. This article employs a museum-based framework to study the design of intrinsically motivating science communication lectures. The analysis was conducted based on the motivational components of the Selinda Model of Visitor Learning (SMVL) proposed by Perry [Perry, D. L. (2012)*What makes learning fun?: Principles for the design of intrinsically motivating museum exhibits*. Altamira Press]**[Q1]**. Using qualitative and quantitative analytical techniques, this study examines the experience of high school students regarding intrinsically motivating elements during their participation in science communication lectures on Chemistry research in Brazil. Two hundred and fifty-eight high school students from six public schools took part in this study, which was primarily based on their visit to a public university. The results obtained showed that the students had a positive perception about the factors that make a lecture intrinsically rewarding and helped identify the specific elements that enhanced students' motivation. Considering that this is the first attempt to apply the SMVL framework in Brazil, the findings suggest that interactive lectures are an important strategic tool that researchers can use to communicate science and their scientific research to the people outside the confines of the university environment and beyond the exchanges that occur between their peers.

KEYWORDS

- Science communication
- intrinsic motivation
- interactivity
- non-formal chemistry education

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Introduction

In many Latin American countries, such as Brazil, apart from teaching and doing research, the universities have also taken on the responsibility of promoting extension activities which are aimed at democratizing and promoting social inclusion through events that bring the university closer to the public (Thorn & Soo, 2006). This kind of extension activity targeted at the general public is an important mechanism to promote the active participation and engagement of the public in science communication. Also, this helps strengthen the relationship between the lay public and the scientific community.

One of the underlying problems related to the design of science communication activities that are often structured based on the 'deficit model' approach in which the modus operandi is to provide the lay public with a considerable amount of knowledge and information. By doing so, the focus is on trying to inculcate in the lay public positive attitudes toward science and increased trust in science and scientists (Cortassa, 2016; Ting et al., 2017).

The most common model in science communication is the one focused on improving the scientific literacy of the public, which is traditionally measured as a combination of knowledge of science contents and scientific methods (Miller, 1998), although other researchers have criticized this approach (Feinstein, 2011). When evaluating the effectiveness of science communication activities, one needs to take into account not only the knowledge that will be discussed with the public or how much they have learned but also the way in which the debate takes place. As pointed out in the literature, activities that arouse students' curiosity and stimulate their involvement might generate opportunities for public engagement in science in both formal (Zion & Sadeh, 2007) and non-formal science teaching environments (Falk et al., 2007).

Considering the need to explore effective ways of conducting public science communication, and through the application of the motivational components of The Selinda Model of Visitor Learning (SMVL) developed by Perry (2012), the present study aims to investigate what makes a public science communication lecture intrinsically motivating for high school students in Brazil. The present study reports the students' participation in one lecture, which was entitled: 'Potential tools for combating corrosion'. This lecture was based on research conducted by a research group in the field of Interfacial Electrochemistry. In the lecture, the problems at hand were corrosion and the major economic and social losses caused by corrosion. The study seeks to provide meaningful insights and novel contributions that can be useful for the design of science communication activities with high school students, especially in terms of creating an intrinsically motivating atmosphere in public and institutional spaces used for science communication. The purpose throughout this paper is to answer and discuss the following question:

- To what extent and how did high school students from urban public schools in Brazil experience intrinsically motivating elements in a chemistry communication lecture?

Science communication in formal teaching

The relationship between the field of research and practice in science education and science communication has been a much-debated and persistent issue for the last decade (Kohen & Dori, 2019). Overall, researchers in both fields work with different theoretical and methodological perspectives, but albeit with some differences in concerns, they aim for similar goals and a commitment to developing positive views, interest, and engagement with science (Baram-Tsabari & Osborne, 2015).

In formal education settings, science communication activities are primarily intended to bring universities or scientists closer to students to promote interest in scientific careers and help demystify the often distorted image of science and scientists (Laursen et al., 2007). In this context, considering the inherent difficulty faced by science teachers to keep up with new developments in science and the growing concern about students' attitudes, interest, and motivation in relation to science, scientific knowledge communication programmes offered by universities can play an important role in promoting the engagement of the younger public in science (Markowitz, 2004). Studies have pointed out the benefits derived from participating in science communication activities conducted within the university, where younger students from high school come into close contact with professional scientists, laboratories, and facilities in the university (Sentanin et al., 2021; Tsybulsky, 2019).

Although these studies have shed light on the benefits that the students gain from visiting a university, very few studies have sought to investigate how to organize the components of a science communication activity and to structure these activities in such a way to make the experience fun. There are several ways in which to structure a science communication or informal science learning activity with students, ranging from using humour as a pedagogical resource (Heras et al., 2020), communicating science using comedy (Pinto et al., 2015), and using experiments for facilitating conceptual understanding (Ting et al., 2017).

Usually, these science communication and informal science learning practices can be evaluated based on individuals' previous knowledge (Shapiro, 2004). However, there are some critics for the usual 'mentalist' approach to previous knowledge as something disconnected from students' social and cultural background (Bricker et al., 2014). A relevant aspect of the aforementioned studies is that a large part of them target students whose interest and skills in science and technology are already consolidated or above average. This profile, however, is not part of the Brazilian reality. According to the results released by PISA 2018 (OECD, 2019), Brazilian students were not able to reach the top of proficiency in science and 55% of them failed to reach the most basic level. Among the main factors associated with this result, socioeconomic status is the most relevant. In this context, seeking to include all students in activities offered by the university becomes a central point within the debate on science communication **[Q5]**.

Interactivity and intrinsic motivation in science communication

One of the ways in which science communication activities can be structured is through interactivity. When it comes to the relationship between science and the general public, the term interactivity has been commonly used in studies that seek to evaluate the effects of museum-based activities on visitors' experiences (Allen, 2004), in the analysis of science communication in the media (Greussing et al., 2020), and science communication events for high school students (Mayhew & Hall, 2012).

Despite the absence of a systematic definition of what interactivity is (Barry & Doherty, 2017; Kiousis, 2002), some authors, like Barry and Doherty (2017), show that the traditional conception of interactivity considers an interactive activity to be constituted either by computational devices in stimulus-responses systems or by components that require physical interactions to reveal a phenomenon. Thus, the traditional concepts upon which interactivity is defined are based on mechanical and behavioural notions of learning as a human-machine relationship (Heath & Vom Lehn, 2008; Witcomb, 2006) with a focus on hands-on activities (Allen, 2004; Van Schijndel et al., 2010); these traditional notions of interactivity exclude from the analysis the internal cognitive processes that are part of the human-machine relationship (Aldrich et al., 1998). With the ample dissemination of the concept of interactivity in the literature, many questions have been raised regarding its appropriate definition (Kennedy, 2004) and its intrinsic effectiveness in science communication, in particular (Heath & Vom Lehn, 2008). Witcomb (2006) defends the separation between the concept of interactivity and its materialization in interactive devices. Other authors have pointed out that interactivity can be an effective tool when well-adjusted to the purposes of a given activity (Adams et al., 2004).

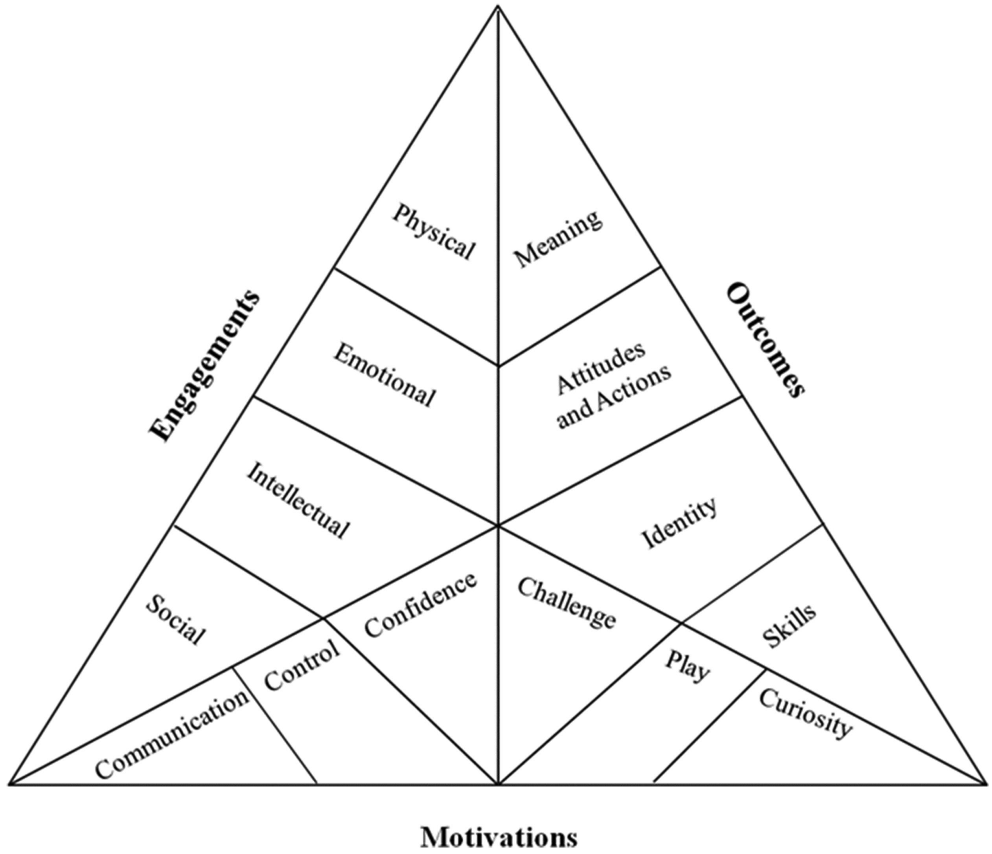
Therefore, in this article, we propose to use interactivity in imaginative ways as both a thinking and practical tool in exploring science education and science communication resources and practices. Following Adams et al. (2004), in this paper, interactivity is conceptualized as 'a range of experiences' (p. 157) that permeates students' engagement with science in personally, physically and affective ways. It is suggested that in this way interactivity can be thought of as a kind of motivational component that drives students' actions. To overcome the mechanical conceptions of learning that emphasize extrinsic stimuli over behaviour, it is proposed that interactivity can be determined from the analysis of student's own cognitive resources that can be mobilized toward the formation of an intrinsically motivating environment (Kennedy, 2004; Ryan & Deci, 2000a).

When individuals feel competent, autonomously engaged, and affectively related to people around them, they become intrinsically motivated for performing a task (Ryan & Deci, 2000b). In this perspective, the association between interactivity and intrinsic motivation emerges as a way of overcoming the mechanical character of interactivity based on stimuli-responses. Yet, this conceptual understanding of the relationship between interactivity and intrinsic motivation is still not well established in the literature; in the case of this work, there is a heuristic value in understanding the relationship between cognitive resources and the design of instructional materials that are suitable for use in science communication spaces.

A museum-based framework

In an attempt to characterize what makes an activity fun, Perry (2012) developed a theoretical museum-based framework, which is referred to as the Selinda Model of Visitor Learning (SMVL), initially called 'Anatomy of a Museum Visit' (Perry, 1993, january). beyond cognition and affect: the anatomy of a museum visit. in visitor studies: theory, research and practice: collected papers from the 1993 visitor studies conference (vol. 6, pp. 43–47). retrieved march 4, 2022 from https://www.informalscience.org/sites/default/files/vsa-a0a4n2-a_5730.pdf.). This model (Figure 1) is based on three components that underlie the learning experience at a museum: (a) outcomes, (b) engagement and (c) motivation. Furthermore, the model was developed to find out what makes an experience intrinsically motivating and how to build that experience, with a focus on the elaboration of museum exhibitions (Perry, 1992, 2012).

Figure 1. Selinda Model of Visitor Learning (SMVL).



As it is emphasized by Perry (2012) the first two components, 'outcomes' and 'engagement', are common in research on museums and science communication research, but 'motivation' remains at its 'conceptual infancy' at least in those settings. With that in mind, the focus of this paper is to explore the experience of high school students in a chemistry communication lecture. But to go beyond 'outcomes' and 'engagement' the purpose is to look at their experience through a motivational lens.

Although the elements proposed by Perry (2012) were meant for the design of museum exhibits, the present study is based on the assumption that these elements, with special reference to the motivational components, can also be extended toward the design and elaboration of any science communication activity. Perry (2012) proposed six motivational components (Figure 1); these include the following: (a) communication, (b) curiosity, (c) confidence, (d) challenge, (e) control, and (f) play. These six components are similar to the three basic psychological needs proposed by Ryan and Deci (2000a) as autonomy, competence, and relatedness which according to the authors when satisfied makes an individual intrinsically motivated for a task. These components are also sub-divided into principles (see Table 1 below).

Table 1. A Summary of The Selinda Model of Visitor Learning's Motivational Components (Perry, 2012).

Components and principles	Definition Summary
Communication 1. Collaboration 2. Guidance	Guiding students on how to perform a task; promoting social interactions in collaborative work
Curiosity 3. Perceptual curiosity 4. Intellectual curiosity 5. Interest	Promoting sensory stimuli and capturing students' attention
Confidence 6. Success 7. Expediency	Promoting high levels of self-efficacy and competence

Challenge 8. Expectations 9. Uncertainty	Challenging students with presentation of clear purposes for a task; creating a situation of doubt and questioning
Control 10. Choice 11. Power	Allowing students' autonomy exercise with choice of activities and modes of learning: what, when and how to learn
Play 12. Imagination 13. Sensory Experiences	Allowing creative thinking, fantasy and use of body senses when interacting with a learning object

The 'communication' component is related to social interactions with other people and the interactions between the people and the elements of an activity, such as reading a text. This component can be defined in terms of two strategic principles: (1) collaboration and (2) guidance. The first is related to the positive relationship between collaborative work and the learning of individuals, while the second focuses on the importance of the presence of elements that help structure and guide learning.

The 'curiosity' component is a kind of force that drives participants to perform a given activity (Perry, 2012). Perry (2012) presents three types of curiosity: perceptual curiosity (third principle), intellectual curiosity (fourth principle), and interest (fifth principle). Perry (2012) states that perceptual curiosity is activated by sensory stimuli, such as lights, sounds, smells, tastes, and textures, which attract the attention of participants. Intellectual curiosity, on the other hand, is what can determine the span of the participants' attention, for example, the conducting an experiment (Benite & Benite, 2009; Perry, 2012; Ting et al., 2017). The principle of interest is proposed as a series of strategies to frame activities from students' interest, previous knowledge, and experiences, paying attention to how 'making unfamiliar things more familiar' (Perry, 2012, p. 110).

'Confidence' is defined by Perry (2012) as the individuals' self-perception of their skills and knowledge. For Perry, it is the adjustment between the self-perception of competence and the level of difficulty encountered that can determine the experience of individuals. Thus, frustration appears as an incongruity between the people' belief in their abilities and the level of difficulty of the activities. There are two interrelated principles associated with 'confidence': success (sixth principle), and expediency (seventh principle). The sense of success is a consequence of the successful interaction of the people with the learning materials, and it is also the cause of a positive perception of the ability to be effective. The seventh principle – expediency, refers to the opportunities offered to individuals for them to quickly develop positive views about their self-efficacy (Bzuneck & Guimarães, 2010).

The component 'challenge' is defined by Perry (2012) in terms of two principles: expectations (eighth principle), and uncertainty (ninth principle). Concerning expectations, the author states that the people will feel challenged according to the level of clarity about what is expected from their participation. The other principle that constitutes the 'challenge' component is uncertainty; this is defined as a situation in which the people are in a state of doubt and realize the need to invest efforts in resolving an issue.

The component 'control', is defined according to the need for individuals to exercise their autonomy. Perry (2012) states that the 'control' component should be defined in terms of choice (tenth principle) and power (eleventh principle) over learning. Concerning the tenth principle (choice), Perry recommends the development of learning activities that provide a set of information that facilitate and allow people to make their own choices. The eleventh principle (power), which is directly associated with the tenth principle, is based on strategies that enable individuals to exercise control over the activity: what, when, and how to learn.

According to Perry (2012), the component 'play' is an integral part of the learning process, and it is not necessarily associated with childhood. Two principles are associated with the 'play' component: imagination (twelfth principle), and sensory experiences (thirteenth principle). Imagination is directly related to the development of creative thinking and the possibilities for intellectual exploration. In addition, Perry proposes sensory experiences as a way of involving the subject's body in activities that stimulate the use of the senses in the interaction with learning objects: physical contacts, smells, tastes, and images are elements that can lead people to have an intrinsically motivating experience.

Design of the study

With this theoretical discussion in mind, a project called Lectures for Science Communication in Chemistry was developed and presented at a public university in the city of São Carlos, State of São Paulo, Brazil, aiming at communicating scientific research in the field of Chemistry among high school students. The lectures were prepared based on partnerships with researchers from the Institute of Chemistry of São Carlos of the University of São Paulo. Although three lectures were developed during this project, the present study only reports the students' participation in one of these lectures, which was entitled: 'Potential tools for combating corrosion'; and based on research conducted by a research group in the field of Interfacial Electrochemistry. In this lecture, the problems at hand were corrosion and the major economic and social losses caused by corrosion, such as damage to the structures of buildings, cars, pipes, bridges, ships, etc. The lectures, as an ongoing practice in university before this research even began, were not initially developed using the components proposed by Perry (2012), although it was based on motivational theories. All this evidence led to the search for a suitable framework that allowed theorizing the experiences of students from a motivational perspective that was specifically focused on making a learning experience intrinsically rewarding. The findings and results are intended to be used to improve these lectures and eventually be applied in developing science communication activities, especially those directed at high school students.

In the quest for creating new possibilities and ways of thinking about science communication activities beyond just content and information, the following research question was proposed for the present study:

- To what extent and how did high school students from urban public schools in Brazil experience intrinsically motivating elements in a Chemistry communication lecture?

Methodology

The present study employed a combination of different data collection methods, both quantitative and qualitative, to enrich our analyzes and validate the data collected in each method (Denzin, 2012). The quantitative analysis was conducted using a questionnaire composed of five of the six motivational components (communication, curiosity, confidence, challenge, and play) proposed by Perry (1992) and based on a 5-point Likert scale. We opted not to evaluate the 'control' component since participation was voluntary and most activities were done under supervision. The qualitative analysis was conducted using a structured interview script with questions based on five of the six motivational components proposed by Perry (1992). The interview script was analyzed by two researchers with experience in the subject in order to identify the clarity of the questions for high school students.

Science communication lectures

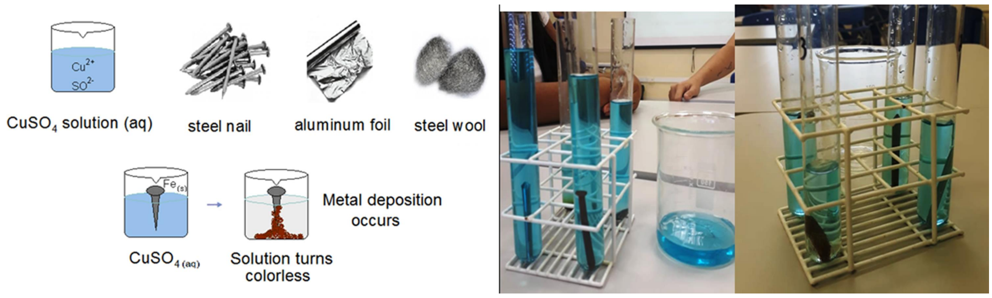
The science communication lectures were made by researchers in the field of science education and science communication together with research groups from the field of Chemistry. In a dynamic and participatory way, the lectures shed light on the process of inquiry pursued by scientists, the infrastructure needed to produce scientific knowledge, and the socio-scientific aspects of the work of scientists. The lectures were conducted using science communication textual materials produced by a PhD student in science education (third author of this article) and pre-service science teachers.

The lectures were prepared using audiovisual resources in slides presentations, and experiments were also carried out; this allowed the students to get actively involved and to make sense of the contents discussed. It is worth noting that the presenters of the lecture were pre-service science teachers who were granted scholarships for the execution of the project. The decision to use pre-service teachers was taken in order to have enough people so that the lecture was presented by at least two speakers/presenters, thus boosting the interactivity of the event. The pre-service teachers received training in science communication to enable them to participate in the production and presentation of the lectures.

The lecture entitled 'Potential tools for combating corrosion' was aimed at presenting the following issues and asking questions related to them: (1) risks and damages caused by corrosion and its relation to broader social problems; (2) understanding how corrosion takes place; (3) discussing and working out alternatives to minimize the problems caused by corrosion; (4) a short presentation made by a Chemistry research group engaged in researching new materials resistant to corrosion; (5) discussing and learning about the process of conducting scientific research in Chemistry; and (6) the relationship between the research presented and the contents of Chemistry taught in high school with a focus on metals and polymers. Further details on this lecture can be found in the Supplementary Material.

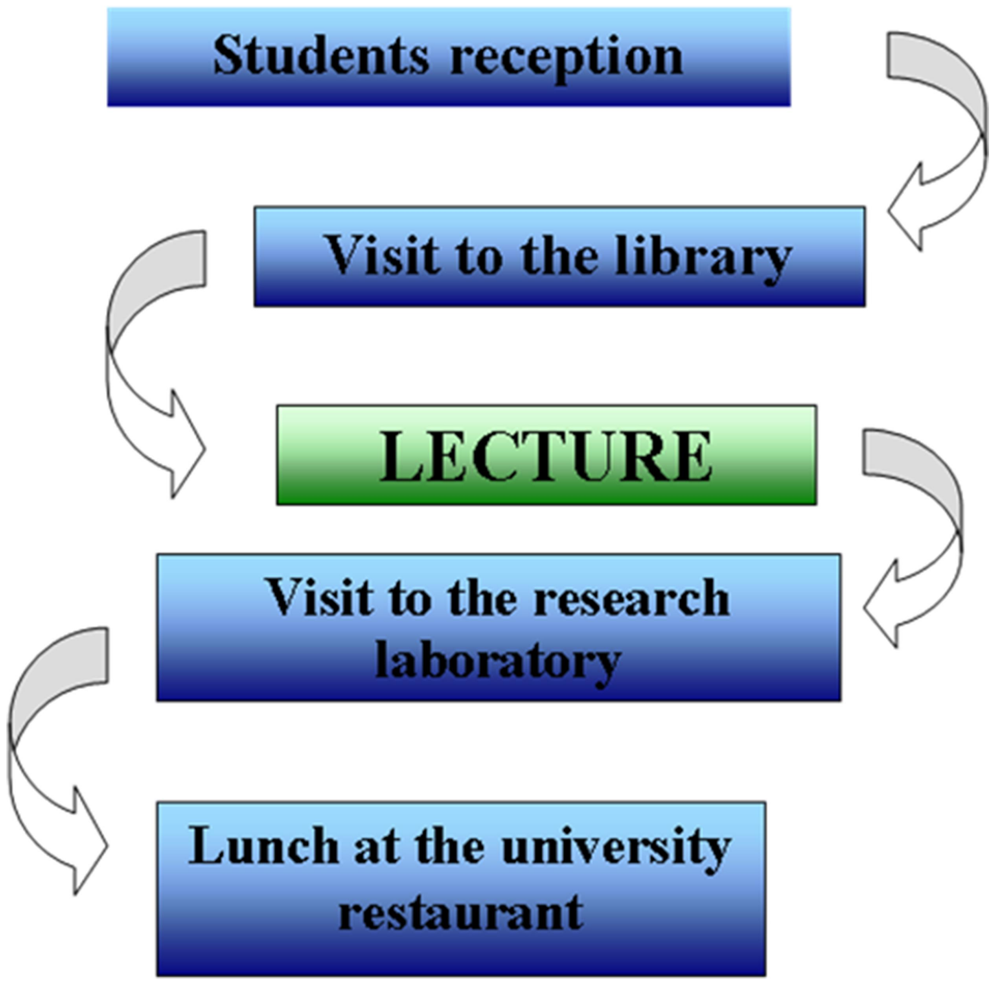
During the lecture, students did an experiment qualitatively comparing the corrosion rate in different materials. Each group received a set of different metals, such as galvanized and non-galvanized nails, aluminium foil, and steel wool. Students immersed the materials in a copper sulfate solution ($CuSO_{4(aq)}$) and analyzed the process of metal oxidation and the reduction of copper ions in the solution. Figure 2 shows a diagram summarizing the experiment carried out by the students.

Figure 2. A scheme and photos of the experiment#.



The lecture, which occurred on a single day, lasted for approximately 90 minutes; each group of students received an invitation to take part in the lecture. Apart from the lecture, students also had the opportunity to visit a research laboratory and the university library and had a lunch break at the university restaurant. Figure 3 presents an outline of the activities offered to the students.

Figure 3. Roadmap of activities offered to students.



Pilot study

There was no quantitative instrument available to evaluate the motivational components proposed by Perry (2012) in the SMVL model framework, so a new questionnaire was developed and tested in a pilot study to ensure its validity (Worthington & Whittaker, 2006).

Initially, a set of 41 items were created and discussed with experts in science/chemistry education. With the exception of the component 'control', each item was elaborated so as to correspond to five of the six motivational components in the SMVL.

For instance, affirmatives were created for the component 'communication' to explore students' experiences of social interactions with their peers or presenters; for the component 'curiosity', to account for how much students felt curious about each element presented during the lecture; for the component 'confidence', to examine how much students felt competent in learning concepts and doing experiments; for the component 'challenge', to explore what are the elements that challenged students the most; finally, for the component 'play', to investigate what elements were most enjoyable for the participants.

The questionnaire was applied to 52 high school students. After this initial study, some items were revised or removed to reduce the questionnaire's size, reaching an instrument consisting of 25 questions with items representative of each of the five motivational components of the SMVL. Finally, these 25 items were examined for face validity by three other researchers with experience in the area. Each item was answered by a 5-point Likert format with response choices 'strongly agree', 'agree', 'I don't know what to think', 'disagree' and 'strongly disagree'. 'I don't know what to think' was added as a proxy for 'neutral' responses or to account for when participants are unsure what they think about the item. Items were scored from 1 to 5, where 1 represents strongly agree, and 5 represents strongly disagree.

To investigate the factorial structure of the questionnaire, a pilot study was carried out with a total of 262 elementary and high school students, with ages varying between 14 and 17 years old. The students came from thirteen different classes in two public schools located in two peripheral neighbourhoods in the city of São Carlos. The pilot study was conducted by the fourth author of this article. The students answered the questionnaire after taking part in the lectures. The instrument was analyzed using Principal Component Analysis (PCA). In a first analysis, six factors were obtained. However, two items had low commonality and factor loading, which implied their removal from the questionnaire. In addition, three other items were removed for further analysis, as they loaded into factors other than the ones originally proposed. However, after removing these items, new ones were created and added to the questionnaire, again resulting in 25 items.

The results of the PCA proved to be adequate. The KMO test recorded the value of .85 with $\chi^2 = 1{,}632.03$ ($df = 190$, $p < .001$). Five components were considered to be representative of the five motivational components of the SMVL model. There were five components with eigen values greater than 1 (Pituch and Stevens, 2015**[Q6]**), and together these components accounted for 57.57% of the common variance.

The five principal components extracted corresponded to the SVML components, and as each item had acceptable loadings (greater than .30), Cronbach alpha statistics were computed to indicate internal consistency of each component. The results were 'curiosity' (α = .82), 'play' (α = .78), 'communication' (α = .67), 'challenge' (α = .56) and 'confidence' (α = .51). The final version of the instrument had 25 items (see Appendix 1).

Participants in the research study

In Brazil, high school lasts for three years, and each student is required to study the same course during this time, including Chemistry. Public state schools in São Paulo are usually attended by low-income students; these schools often face structural and financial problems, including lack of teachers and poor facilities. Also, these are located in areas where there are no public spaces for leisure and cultural activities.

Two hundred and fifty-eight high school students from six public schools in the city of São Carlos participated in this study (50.8% female; the students were aged between 14 and 24 years of age). These public schools were chosen as a way of reaching low-income students in the region. The participating students came from the three different grade/years of high school based on the following distribution: 26.0% in the first grade/year; 39.5% in the second grade/year; and 34.1% in the third grade/year. The lectures took place during the year 2019.

All the students sought authorization before leaving their schools. All students were informed about the purpose and development of the research and about the freedom to stop participation at any time. The research project was evaluated and approved by the Research Ethics Committee of FFCLRP-USP (CAAE n° 79434717.6.0000.5407).

Instruments

As aforementioned, two instruments were used to assess the students' perception of interactivity of the science communication lecture: a quantitative instrument, which was developed during the Pilot Study and presented in Appendix 1, and a qualitative tool, which was based on a structured interview script devised according to the interpretive approach.

The interview was based on both the motivational components proposed by Perry (1992, 2012) and the questionnaire items. The interview consisted of a total of six questions – five questions were elaborated with the aim of investigating the students' experience of the interactivity of the lecture and a sixth open question was elaborated to allow the students to make general comments about their experience (see Appendix 2). As a structured script, each interview lasted for about 2–4 minutes. Students were told that their responses would be kept confidential and anonymous.

Data collection and analysis

At the end of the lecture, the students were asked to answer the quantitative questionnaire. The questionnaires were distributed on paper to the students, who answered them in approximately 20 minutes. The students were assured of the confidentiality of their answers. A total of 258 valid questionnaires were collected – this number is in line with the findings of the study conducted by Hair et al. (2006) who recommended the use of ten respondents ideally for each number of items in a research instrument.

Two schools were selected to take part in the interviews. The interview was scheduled approximately 9 weeks after the lecture, to avoid scheduling problems related to the timetable for the activities that had already been programmed by the schools. Twenty-six students were interviewed, fourteen girls and twelve boys; this corresponded to approximately 10% of the quantitative sample (Fraser & Gondim, 2004). The participation of each student was voluntary and confidential, and to maintain student confidentiality, pseudonyms were used in reporting the qualitative results.

Data analyses were performed in two stages by the first and second authors of this article. First, quantitative data collected from the Likert scale instrument were analyzed to obtain descriptive statistics, including the means, standard deviations, Cronbach Alpha coefficients and the conduct of *t*-test analyses. The statistical calculations were done using the SPSS 17.0 software (Statistical Package for the Social Sciences). Qualitative data were analyzed using a simple categorization process. Initially, audiotapes were transcribed and analyzed in order to identify common characteristics in the participants' statements. All the qualitative data were evaluated based on the five motivational components present in the quantitative questionnaire.

Results

Quantitative results

Table 2 reports the means, standard deviations and internal consistency values obtained for each component. The results obtained show that, in general, the students had a positive perception relative to the factors that point to the interactivity of the lecture. The five components exhibited satisfactory internal consistency with values between .62 and .79. According to (Taber, 2018), these values lie between moderate and fairly high, indicating that the instrument is reliable.

Table 2. Mean values and standard deviation for each component evaluated.

Components	Items	Mean	SD	Cronbach's alpha
Curiosity	1, 6, 11, 16, 21	1.91	1.08	.77
Play	2, 7, 12, 17, 22	1.42	.78	.79
Communication	5, 10, 15, 20, 24, 25	1.43	.83	.65
Challenge	3, 8, 13, 18, 23	2.29	1.24	.68
Confidence	4, 9, 14, 19	1.67	.90	.62

Independent *t*-tests were performed to determine if there were differences between males and females in mean scores on each component of motivation. The result was considered statistically significant when $p < 0.05$. For the components 'curiosity', 'play' and 'confidence', no statistically significant differences were observed. In contrast, the mean values related to the components 'challenge' and 'communication' showed statistically significant differences. Table 3 reports these results, with the lower mean scores for female students indicating more positive perceptions for both components. It should be remembered that lower scores in this case represent more positive perceptions about each component.

Table 3. Values of mean and standard deviation for each component evaluated, according to the respondents' gender.

Subscales	Gender						
	Female		Male		*t*	*df*	*p*
	M	(SD)	M	(SD)			
Curiosity	1.86	.76	2.00	.79	1.21	244.00	.22
Play	1.38	.50	1.50	.64	1.31	241.00	.19
Communication	1.37	.44	1.51	.59	2.10	214.10	.02
Challenge	2.18	.80	2.43	.84	2.34	246.00	.03
Confidence	1.62	.57	1.73	.69	1.40	244.00	.16

From these results, it can be concluded that the lecture presented to this audience may have contributed to the 'play' component (M = 1.42), aroused their 'curiosity' (M = 1.91), effectively promoted 'communication' (M = 1.43) between the participants and the speakers, created a medium in which the 'confidence' of the students was found to be generally high (M = 1.67), and promoted situations that represented a 'challenge' to the participants (M = 2.29). Interestingly, the 'challenge' component was the most controversial of all the components because, compared to the other four components, the mean score obtained for this component was much closer to 'I don't know what to think' (3) response.

Qualitative results

Curiosity. The first question of the qualitative questionnaire evaluated the 'curiosity' component. Most students (*n* = 20) provided an affirmative answer; only 6 students of 26 interviewees responded that their curiosity was not aroused during the lecture.

Nine participants were curious during the experiment: 'at the time of the experiment that we did, (…) It was pretty cool' (Pedro, male, 17). Eight students felt curious about metal corrosion: '(…) during the explanation of how metals corrode, I was very curious' (Karen, female, 17). Some students felt curious especially about aspects related to their daily life, what they see in the media, and their parents' occupation:

> The part of the lecture that I thought was the coolest was the experiment. As my grandfather is a construction worker, (…) we usually see that when it rains the irons are easier to rust, so I found it very interesting. (Rosa, female, 16)

One student mentioned a part in the presentation focused on discussing how a university works. Images and videos shown during the lecture as curious artefacts were mentioned by three students. One student mentioned the research laboratory they visited as part of the whole visit programme to the university.

Few students (*n* = 6) responded that their curiosity was not aroused during the lecture. For some of these students, the fact that they understood everything that was done during the lecture satisfied any curiosity they had before the lecture: 'No. They explained it well, I understood everything correctly' (Wilson, male, 16).

Play. The second question was related to the analysis of the 'play' component and all but one of the 26 students gave a positive answer (yes). The components that most contributed toward making the lecture fun were the interaction and participation of the majority of students during the presentation of the lecture (*n* = 16) 'because rarely someone participates in something' (Maria, female, 16). The fact that they left their classrooms (*n* = 5) was also mentioned as an element of fun. The experiments conducted during the lecture were mentioned by four participants because it was a moment they had to do something practical and not only listen.

Only one student mentioned the presence at the university as something fun. According to her, 'The visit added a lot to our life. (…) They tried to entertain us, playing, interacting, and that was very good.' (Roberta, female, 16).

Communication. All the students responded that there were interactions between most of the students (*n* = 26) in the class. Some students stated that interactions occurred throughout the entire lecture (*n* = 14), while other students stated that interactions occurred at certain times (n = 12). Eight students identified the period in which the experiment was carried out as the moment when interactions mostly occurred. Six students stated that the interactions occurred mainly when the presenters asked questions, and according to one of the students, presenters were the entire time close to them which made her think that 'They were very friendly (…)' (Roberta, female, 16). The other students (*n* = 12) did not mention specific moments where these interactions occurred. The more active participation of some of the students, especially boys who '(…) started to mess around there' (Rod, male, 16), was contrasted to those who felt shy during the lecture: '[they] could have interacted more, right? But because I know them and I know they are very shy, they kind of interacted well' (Rosa, female, 16).

Confidence. All the 26 students gave a positive answer (yes) to the fourth question related to the component 'confidence'. For some of them, the confidence for working with Chemistry might be related to their initial interest and how they think about themselves concerning their school achievement. One student said that if he studied he could work in this field because 'I'm good at Chemistry. You can ask the teacher from here [the school]' (Will, male, 18). Another student has already thought about herself working in a related field before the lecture, as she mentions that '(…) I am very interested in Chemistry, in the area where I am going to work there is Chemistry.' (Paula, female, 16).

Challenge. Concerning the 'challenge' component, the students gave several different responses. For the part of the lecture that they found to be 'easier', some students said that everything was easy (*n* = 5). Other students (*n* = 15) found the experiment part to be easier. As mentioned by one student the most difficult was '(…) understanding how it works (…) and the easiest is doing, having your hands dirty, you know, the action' (Caleb, male, 17). The rest (*n* = 6) of the students said they found some aspects of the lecture and the dispositions required – such as explanation, interaction, and paying attention, to be easier. Again, some students commented that the ease of the lecture was because 'they [the presenters] managed to make us understand everything in our language, like in our daily life, so it was easier' (Rosa, female, 16).

With regard to the part of the lecture that they found to be the 'more difficult', most students said that there was nothing difficult (*n* = 13). Other students said that they found some of the questions asked by the presenters to be the most difficult aspect (*n* = 7), and the rest (*n* = 6) said they found other aspects like the experiment, paying attention, being well-disciplined, and speaking in front of others as the most difficult part.

In the last question, students were asked to express themselves freely. Some (*n* = 10) of the students said there was nothing to talk about; however, most of the students (*n* = 16) expressed the desire to have more events like the lecture and said that they had enjoyed taking part. According to one student, 'we left [the university], we came on the entire bus talking that we had enjoyed it a lot, and if we had a second opportunity to go, we definitely would go' (Rosa, female, 16).

Discussion

Curiosity: An analysis of the interviewees' reports showed that among the elements that most aroused students' curiosity was the experiment carried out during the lecture, and when the theoretical content was focused on showing chemistry phenomena in their daily life and its relation with their families' occupation. Since some students mentioned they are not used to this type of activity, there is an element of surprise when performing then. This result shows that the conduct of an experiment can be a fundamental element in science communication activities (Ting et al., 2017).

Unsurprisingly, the university itself is a curious element for students. Although the university is geographically close to them, it might still be culturally distant (Smyth & Banks, 2012) for some and the visit is a great opportunity for them to acquire the knowledge necessary to how it works.

Play: Humour and jokes were an important aspect of interacting with these students, and just changing their learning environment can be an element of fun. These findings point to the need to structure science communication activities in a dialogue format where affective relationships between participants are stimulated, but also means interacting with students in a way that they usually interact with themselves using humour as an important relief element. Communication in this case is not only about having social interactions but also about the way these interactions are framed and brought to the front stage of the lecture.

Although Perry (2012) defines the component 'play' as something associated with imagination and sensory experiences, particularly in this research students experience play as acting silly and making jokes. This does not exclude what Perry (2012) recommends, but it goes beyond by disentangling what it means to have fun during a lecture with high school students. Some authors have already argued for using humour as a pedagogical approach (Heras et al., 2020) and how it promotes an atmosphere conducive to learning (Osborne & Collins, 2001).

Communication: Students highlighted two fundamental moments of social interactions: the execution of the group experiment and when they were questioned by the presenters. As shyness was an aspect frequently mentioned in the interviews, it might be that for some students participation and engagement don't equate talking and being physically active, but just paying attention as a form of intellectual engagement. This is the opposite of some students, especially boys, who were mentioned as disturbing the lecture, which also might explain why the girls' perception of this component was found to be generally more positive.

For the participants, it is important that they are treated well and this indicates that social interactions must be qualified in a way respectful for their way of being especially when students come from disadvantaged communities and schools.

Challenge: This component was the one that recorded the least positive score. Some students pointed out that they either had sufficient knowledge about the concept being discussed or preferred to conduct more difficult experiments, but generally they contrasted the ease of doing the experiment with the theoretical part. This means scientific language and the way it was framed was the main obstacle for students learning in the lecture, the opposite of using manual abilities in the experiment.

Others reported difficulty in answering the questions asked by the presenters. These differences may have stemmed from the fact that the students lacked knowledge about all contents presented. As the students were from different grades/years in high school, their knowledge of Chemistry was not homogeneous. For instance, the concept of oxidoreduction addressed in the lecture is covered only in the second year of high school, so the students from the first year were unfamiliar with the concept (São Paulo, 2011).

Differences were also observed in terms of the gender of the respondents, with the girls having a relatively more positive perception of challenge. It might be that, different from what was experienced by some boys, the lecture was ' (...) setting appropriate expectations and designing for an appropriate level of uncertainty' (Perry, 2012, p. 150) these girls already had before the visit, or they might simply be more skilled with chemistry than boys in their class. Although girls and boys performed similarly in science in PISA tests(OECD,2019), this might not be the case for disadvantaged schools or particularly in chemistry.

As this research indicates, although students might have had some difficulty in understanding theoretical concepts, they seemed comfortable in performing experiments. As prior knowledge has been usually framed in terms of cognitive knowledge (Shapiro, 2004), the conclusion is to think of students in terms of cognitive deficit. But as students' reports have shown, they still feel confident when it comes to using manual abilities. In this situation, one cannot neglect that 'prior knowledge' might also be related to manual abilities which structure an individual's learning experience.

Confidence: Finally, about the 'confidence' component, all the students gave a positive answer when they were asked about the possibility of working in the field of Chemistry. But students' confidence in working in this field might be closely related to their previous sense of competence and success in school or their prior interest in science (Perry, 2012). This means it is difficult to disentangle how specifically the lecture may have boosted the confidence in pursuing a scientific career in Chemistry from how they thought about themselves previously to the visit. Although they all felt confident in working in the field of Chemistry, the lecture might have boosted not their sense of entitlement for a scientific career, but mainly their interest in the university itself.

Although the results found by Bonnette et al.(2019) showed that the participation of students in scientific activities outside the school boosted their interest in science and other science-related careers and this is especially relevant during high school and among minority groups (Kitchen et al., 2018), this research indicates that there is also a need of exploring how students think about themselves in relation to university when participating in this kind of project and how going to college is an 'imagined future' for them. Informal science learning offered by universities is thus crucially important in stimulating the interest of young people and motivating them to pursue science courses.

Limitations

Some limitations were observed in the conduct of this study. First, it would be interesting to apply other quantitative instruments to enrich the results through correlation and causality analyses, and qualitative ones through observations. Secondly, considering that the study involved participants from the same region, the generalizability of the results is restricted. Also, although open-ended, the interview guide was composed mostly of leading questions and, as consequence, it could have directly influenced students' responses.

Another limitation was that initially the lectures were structured based on Self-Determination Theory(Ryan & Deci, 2000a; 2000b). However, the purpose of this article was to study specifically what makes this lecture fun for students and the SVLM was particularly developed to answer this type of question. The scope of the work is limited in the sense that the study evaluated the interactivity involving only one element of the students' visit to the university – the science communication lecture. Other activities, such as visiting the laboratory, interacting with scientists, and visiting the library were not evaluated; clearly, these activities may exert some influence over the students' perception.

Conclusions and future implications

The main objective of this paper was to investigate how high school students from urban public schools in Brazil experience interactivity from an intrinsic motivation perspective during their participation in science communication lectures in the area of Chemistry. As noted in the present study, although interactivity is an indispensable element of communicating scientific activity, it is, however, often difficult to achieve; this is mainly due to the fact that interactivity is usually linked to extrinsic motivation and mechanical relations. Linking interactivity to intrinsic motivation can be a good way of changing the focus of science communication design from the environment itself to the internal psychological resources of the participants.

This research goes beyond Perry (2012), although firmly associated with the SMLV, by discussing that what makes a lecture fun for this group of students is closely associated with their interest and readiness in working with practical and manual tasks, and their focus on humour as one of the main factors of a good social interaction. Also, the visit itself was a component of curiosity for these students and it is impossible to dissociate the analysis of their experience from the novelty of simply going to a university. Perry (2012) does not state 'what makes learning fun' for boys or girls, however, this research shows there can be a difference: girls, when compared to the boys, felt more challenged and had a more positive perception of moments of social interactions during the lecture. This might be related to how they expected the lecture to be, although the research does not have enough data to support this statement.

The findings of this research have important implications in the area of science communication because, to date, no study has sought to measure the interactivity of science communication activities in Brazil based on the components proposed by Perry (1992, 2012). Thus, we expect that the present study will contribute to the enrichment of the debate and the advancement of this area through the development of new approaches to science communication and its evaluation.

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Appendices

Appendix 1. Outline of the items related to each of the components proposed by Perry (2012).

Item	Sentence	Component
1	I was curious about what the university does.	Curiosity
2	It was fun to manipulate objects.	Play
3	I felt challenged to learn more about what is done in the university.	Challenge
4	I understood the proposal of the lecture.	Confidence
5	The presenters were able to communicate with everyone in the class.	Communication
6	I thought the lecture aroused my curiosity.	Curiosity
7	I had fun with the images and examples presented.	Play
8	I felt challenged to study more about some of the concepts presented in the lecture.	Challenge
9	I felt confident to participate.	Confidence
10	Communication between the participants helped me to understand better.	Communication
11	I was curious about Chemistry.	Curiosity
12	I enjoyed participating in the group activities.	Play
13	I can explain the subject of the lecture to someone else.	Challenge
14	The presenters' explanations made me feel safe to participate in the lecture and activities.	Confidence
15	The opinions of the participants were considered.	Communication
16	I was curious about the Chemistry experiments.	Curiosity
17	It was fun to carry out the experiments.	Play
18	I felt free to ask questions about things I needed to know.	Challenge
19	It was clear to me how to perform the experiments.	Confidence
20	I had the opportunity to exchange ideas with my colleagues.	Communication
21	I was curious about the work of the research group.	Curiosity
22	I had fun participating in the lecture.	Play
23	I felt challenged to do the experiment.	Challenge
24	The lecture and activities were presented in a very clear and comprehensible manner by the presenters.	Communication
25	I thought the lecture promoted an exchange of ideas and opinions.	Communication

Appendix 2. questions prepared for the structured interviews with the students.

Components	Questions
Curiosity	Were you curious about any moment of the lecture? Which one? Can you describe the moment?
Play	Would you say the lecture was fun? Why?
Communication	Did you feel that you and your colleagues interacted with the presenters? Was it during the whole lecture? In what moment?
Challenge	What do you think was easier and what was more difficult when participating in the lecture? Tell me a little about how you felt.
Confidence	By participating in the lecture, do you believe that, if you wanted and studied, you could also work with Chemistry?
–	Leave a comment or suggestion.