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Motivation to learn through interactive lectures: a chemistry research popularization

Motivação para aprender por meio de palestras interativas: a popularização da pesquisa química

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Abstract: Science popularization projects have been studied from different points of view and theories. However, little is known about how they can affect the motivation to learn. In the present study, the contribution of interactive lectures to motivation to learn chemistry in public school students was analyzed. Four interactive lectures were developed from the partnership between the authors of the present study as science communicators and different research groups of a public university in Brazil. The lectures were presented in a science museum and in the university to around 150 students of three public schools during one year and were analyzed through the Self-Determination Theory. The Intrinsic Motivation Inventory revealed that the lectures promoted the interest, value of chemistry, effort and perceived choice to the detriment of the sense of pressure to learning chemistry. The interviews also showed that the students became more interested and dedicated in chemistry. The results foment the potential of the interactive lectures for motivation to learn and the responsibility of public universities with science popularization projects.

Keywords: lectures of chemistry, science popularization, self-determination theory.

Resumo: Projetos de divulgação científica têm sido estudados sob diferentes pontos de vista e teorias. No entanto, pouco se sabe sobre como eles podem afetar a motivação para aprender. No presente estudo, a contribuição de palestras interativas para a motivação para aprender química em alunos de escolas públicas foi analisada. Quatro palestras interativas foram desenvolvidas a partir da parceria entre os autores do presente estudo como divulgadores científicos e diferentes grupos de pesquisas de uma universidade pública no Brasil. As palestras foram apresentadas em um museu de ciências e na universidade para cerca de 150 alunos de três escolas públicas durante um ano e foram analisadas por meio da Teoria da Autodeterminação. O Inventário de Motivação Intrínseca revelou que as palestras promoveram o interesse, valor da química, esforço e escolha percebida em detrimento da sensação de pressão para aprender química. As entrevistas também mostraram que os alunos passaram a se interessar e se dedicar mais à química. Os resultados fomentam o potencial das palestras interativas para a motivação para aprender e a responsabilidade das universidades públicas com projetos de divulgação científica.

Palavras-chave: palestras de química, popularização da ciência, teoria da autodeterminação.

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The increasing involvement of scientists in science popularization has been occurring through several activities such as dramatizations (Dowell and Weitkamp, 2012; Moreira and Marandino, 2015), stand up shows (Pinto *et al.*, 2015), scientific dissemination video (Sentanin, Lanza and Kasseboehmer, 2023) and science fairs (Martín-Sempere *et al.*, 2008; Illingworth *et al.*, 2015). Lectures, demonstrations and workshops offered by scientists or science communicators are also possible strategies for science popularization. Although the lectures are known as activities composed exclusively of oral exposure with the use of PowerPoint (Gier and Kreiner, 2009), they can also be interactive and playful (Sentanin *et al*., 2021).

In addition to the types of strategies, science popularization has been the object of study in the most varied areas of knowledge. They have been evaluated in terms of the scientific communication model (Palmer and Schibeci, 2014), the participation of scientists and audience receptivity (Pinto *et al.*, 2015), the public understanding of science (Scheitle and Ecklund, 2017), the attitudes and perceptions of researchers towards public communication (Merino and Navarro, 2019) and the promotion of interest in scientific careers (Illingworth *et al.*, 2015).

The use of science popularization to promote motivation to learn is still uncommon. Motivation has been more explored in the schools, as in the use of active methodologies and virtual environments (Palmer, 2009; Vaino *et al.*, 2012; Dias and Penido, 2021). However, science popularization has the potential to be explored in the educational psychology area. Especially when they are of a ludic-experimental nature, they seem to be aligned with the satisfaction of motivational factors. Guzzi (2014) evaluated the motivational aspects in mini-courses of chemistry in a science center and showed that they promoted more self-determined forms of motivation that remained 20 years after participation. In this paper, the need for science popularization actions that can maintain or increase the motivation of public school students to learn chemistry are discussed. Besides this, it is argued that dialogue with society is the responsibility of the public university.

Using the Self-Determination Theory (SDT), the promotion of motivation after students' participation in science popularization lectures of chemistry was evaluated, based on the following hypotheses:

i) lectures can supply the psychological needs that motivate the individual; and
ii) it is possible to overcome the deficiency of this kind of initiative in Brazil.

Science and science popularization in Brazil

In Brazil, scientific research occurs predominantly for noncommercial purposes and in public universities through resources from government agencies, research councils or philanthropic entities. Among the Brazilian states, São Paulo has the highest productivity and funding, and the University of São Paulo (USP) is the public institution of research and higher education that leads the scientific and academic production in the country (Dudziak, 2018). USP has six campuses distributed across the State and one of them is located in the city of São Carlos. The city has another renowned public university and the titles of National Capital of Technology and "city of doctors" due to the high number of doctors per inhabitant compared to other cities in Latin America. However, the population of the city, especially public school students, has low understanding about universities and their role in society (Parra, Silva and Kasseboehmer, 2015). Moreover, the latest survey on public perception about science and technology in Brazil (Brasil, 2018) indicates that Brazilian society has an interest in science, but still feels distant from this reality and has difficulty to access this sort of information. In addition, Brazilian basic education fails to promote the integral formation of students and deepens the social and cultural exclusion of the popular classes that do not compete in better conditions to join public universities, of better quality than the private ones.

Both the low interference of the public university in basic education and its indifference about what is disseminate about science show the distance of the public university from what originally legitimized it: to be a social, autonomous and democratic institution, that has the society as its principle and its normative and evaluative reference (Chauí, 2003).

There are several problems that emerge when science has little prestige among the general population (Sentanin *et al*., 2021). Chemistry, for example, is involved in all productive sectors. However, few people recognize its relevance because they do not relate it to advances in areas such as medicine, energy, food and the environment. Even in museums and science centers, chemistry is under-represented because of the need for constant monitoring and the risks with safety (Silberman, 2004). It should be noted that there are works to popularize science being carried out in museums (Rocha and Marandino, 2017; Colombo Junior and Marandino, 2020), but few deal with the topic of motivation to learn chemistry.

These aspects confirm the need for science popularization in order to include society in decision making, to motivate students to learn chemistry, and to stimulate students' interest in scientific careers.

Self-Determination Theory (SDT)

The promotion of more autonomous forms of motivation can be studied through SDT (Ryan and Deci, 2000). The origins of the construct of self-determination lie in philosophy and discourse on the doctrines of determinism and free will. Self-determination or self-determinism as a psychological construct refers to voluntary and self-induced action that is based on its own will (Ferreira *et al*., 2021).

According to the SDT there are two types of motivation, intrinsic and extrinsic. Intrinsic motivation originates from internal individual factors, it is related to his/her way of being and personal interests. This type of motivation is constant, since it depends only on the subject and not on external factors. Extrinsic motivation, on the other hand, originates from factors which are external to the individual (Boruchovitch and Guimarães, 2004).

Intrinsic motivation reflects positive potential in human nature, due to the search for novelties and challenges, such as exercising the ability to explore and learn (Ryan and Deci, 2000). Thus, intrinsic motivation provides human beings with their development of autonomy and personality, based on internal reasons that are not dependent on external rewards (Tresca and De Rose, 2000). Within SDT, Ryan and Deci (2000) specify factors that explain the variation in intrinsic motivation, and the environment can make this motivation easy or hard. Activities that provide opportunity, positive feedback, allowing a sense of autonomy, contribute to the increase of intrinsic motivation. In the school environment, intrinsic motivation appears when the student is curious to learn and persists in performing tasks. Even when he/she finds it difficult to understand the activity, he/she spends time developing it and feels happy to be able to do it (Martinielli and Bartholomeu, 2007).

Extrinsic motivation is not a static concept. Through the process of internalization, the extrinsic motives can be transformed into more personal values leading to a continuum of internalization of external regulations (Appel-Silva *et al.*, 2010). In SDT, social variables play a significant role in self-determination and are important mediators in interventions that seek to promote it (Ferreira *et al.*, 2021). Ferreira *et al.*, 2021 have shown that activities and school projects that incorporate choice, variety and challenge promote interest and value perception. On the other hand, studies have also shown that the use of extrinsic impositions or rewards in order to engage the student can initially raise the motivation, but over time the rewards tend to condition the student's involvement (Austin *et al.*, 2018).

In a school environment, as in other environments, SDT requires three basic psychological needs for intrinsic motivation to occur: the need for autonomy, the need for competence and the need to belong or establish bonds (Deci and Ryan, 1985). Thus, in situations of school learning, interactions in the classroom and at school need to satisfy three basic psychological needs for intrinsic motivation and self-determined forms of extrinsic motivation to occur (Boruchovitch and Guimarães, 2004). Regarding chemistry, the low motivation for its learning has been confirmed because of its nature and the way it is taught in the classroom (Sentanin *et al.*, 2021).

For Palmer (2009), the emphasis on practical activities and research through the inquiry method can be a fertile field for creating situational interest. Using SDT, Black and Deci (2000) studied the effects of autonomy-supportive teaching on American students' motivation to learn organic chemistry. They observed that students' perceptions about teachers' autonomy-supportive style predict increases in self-regulation, perceived competence, and interest while decreasing anxiety.

Cetin-Dindar and Geban (2017) investigated the effect of instruction oriented on the learning cycle model on the conceptual understanding of 11th grade students on acids and bases concepts and on students' motivation to learn chemistry. They observed that the students in the experimental group obtained greater motivation and this difference was considered statistically significant. Salta and Koulougliotis (2020) investigated the question of the specificity of the domain of motivation in specific science subjects (chemistry and physics) in combination with influencing factors related to students' academic training and gender. Discipline-based comparisons showed the existence of specific domains in motivation with the entire sample of students showing greater motivation to learn chemistry in relation to physics in all five SMQ II motivational scales (self-efficacy, self-determination, intrinsic motivation, career motivation and grade motivation). Austin *et al.* (2018) describe a study that aimed to characterize the important motivating factors for general organic chemistry students and how such factors connect and correlate with student performance. The results suggest that students were highly motivated to obtain a high grade, but that the motivation in this grade correlated only weakly with performance.

Considering these literature findings and the Brazilian educational problems, it is important that scientists interact with society. In this way, the aim of this study was to evaluate the contribution of lectures about chemistry research to motivation to learn chemistry using the SDT as a theoretical reference.

This study attempted to answer: Can the participation of lectures of science popularization satisfy the basic psychological needs of students and promote the motivation to learn chemistry? It is believed that the results can contribute to future interventions for students' motivation and the approximation between university culture and society.

Methods

The interactive lectures developed

The interactive lectures are playful and experimental activities developed by a research group that studies chemistry popularization and motivation to learn chemistry among other areas of research. The scientific communicators seek to present the chemistry researches that occur in the universities by different research groups. The research is contextualized through historical, social, environmental, economic or technological approaches and focus on one substance or technique used by the research group as an example. The elements present in the interactive lectures satisfy Gilbert and Stocklmayer's (2001) interactive exposition model, which aims to understand the entertainment and learning perspectives from four components: target; experience; public understanding of science and technology; and memories.

The first author and undergraduate students of chemistry that received specific training in science communication presented four interactive lectures. The researches disseminated were from Chromatography Group (L1), Medicinal Chemistry Group (L2), Group of Electrochemical and Environmental Processes (L3) and Interfacial Electrochemical Group (L4), all of the same department. Most of the research groups never had any contact with scientific popularization, but accepted the partnership and the possibility of having their research disseminated to students outside the university.

L1 discusses the contamination of soil and water by drugs commonly used in health care. This may occur during the pharmaceutical production, elimination through the urine and feces of patients and incorrect disposal of drugs with expired validity. Students are asked how they could identify if the water in a river is contaminated. Norfloxacin, an antibiotic studied by the group, is used as an example. Students perform the paper chromatography experiment in groups. They compare the results according to the colors of the pens and hypothesize on how the substances were separated. The concepts of substances and mixtures are discussed. Finally, students are introduced to the advanced methods for separating mixtures used in the laboratory through videos and the manipulation of equipment used by the research groups. The importance of monitoring the contamination of water and soil through chemical analysis for further treatment is emphasized. Furthermore, the high consumption of drugs, the process of increasing bacterial resistance and the correct mode of drug disposal are discussed.

L2 discusses stages of drug development, highlighting how a chemist can act in this process. In this lecture, the communicators remember the high consumption of medicines and present data on the increase of diseases like cancer. Some of the substances studied by the group for the treatment of prostate cancer are addressed and a colorimetric experiment is conducted to discuss how spectrophotometry is used in the toxicity studies, showing that these studies are essential in the early stages of drug development. In this experiment, groups of students mix chemical reagents at different concentrations and come to consensus on the order of the beakers according to the color intensity of the final solutions. Finally, the presenters approach spectrophotometry through photos and videos, showing the importance of using techniques sensitive to differences in concentration imperceptible to the naked eye.

L3 addresses the aquatic and terrestrial contamination by dyes, drugs and pesticides and presents to the participants the electrochemical processes as possible treatments of these contaminated matrices. Presenters ask students about the importance of colorants to human life and show how they have been targeted for research aimed at their degradation. The degradation experiment of the reactive dye Blue 19, an environmental contaminant, is carried out by the students through the agitation of a dye solution with steel wool and the addition of hydrogen peroxide. Each group of students chooses a variation of the experiment and compares the time for the solution to become colorless. Scientific communicators discuss the substances produced and their effects on certain organic compounds. They also relate the need to use analytical chemistry, discussed in the previous lectures, to verify the degradation.

In L4 the science communicators show images and news about real accidents that occurred due to metal corrosion. They emphasize the economic and security problems behind this process and students are asked how to overcome them. The work developed by the research group that aims to prevent or reduce the natural process of corrosion through protection with polyaniline, are discussed. During the lecture, students conduct several experiments comparing the speed of corrosion in different media and samples of metals protected or not by polyaniline and the importance of this kind of research for the society is discussed.

The presentation took place at the science museum of the city and in the University library. The spaces have been adapted to make them more suitable for the presentation of the lectures. For example, the Chemistry Tunnel about the History of Chemistry. At the entrance of the tunnel students take head flashlights to cross the tunnel and explore objects.

Participants

Participants were students from three public schools (A, B and C) aged between 15 and 18 years old and enrolled in the first year of high school.

School A is traditional in the city. Some of the students need to work after school and have little expectation of attending a public university.

School B is medium sized. Most students are expected to attend university entrance exams and a small part of them is usually involved in educational projects after school.

School C is located in a peripheral region of the city. Students are generally needy and sometimes transferred to this school for reasons of difficulty in learning or discipline. Several students work after school and do not show expectation of entering higher education.

Although the three schools have science labs, chemistry teachers and students said they are rarely used. Table 1 shows the distribution of participants according to school and gender.

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 (CAAE nº 79434917.2.0000.5407).

Data collection

In this study, the triangulation was applied (Yin, 1994), combining a Likert scale questionnaire, interviews with students and teachers and observations.

Table 1: Distribution of participants according to school and gender.

Lecture	Number of students per school and gender									Total
	A			B			C			
	Boys	Girls	Total	Girls	Boys	Total	Girls	Boys	Total	
L1	18	26	44	37	21	58	9	22	31	133
L2	12	27	39	39	32	71	13	30	43	154
L3	8	20	28	24	31	55	11	16	27	110
L4	12	21	33	28	23	51	14	16	30	115

Based on the SDT, the Intrinsic Motivation Inventory (IMI), modified from McAuley *et al.* (1989) and Deci and Ryan (2005), was used. The IMI evaluates the participant's subjective experience in a practical activity. The items are divided into six subscales, being: interest, perceived competence, effort, value, pressure and student's perceived choice while performing a certain task. The English questionnaire passed through a cross-cultural translation, which took into account the official language and the destination culture. The IMI items were modified and some of them were excluded to meet the specific activities of the interactive lectures. Consequently, the questionnaire had 27 items and some of them must have a reverse score because they are negative sentences.

For the qualitative data collection, semi-structured interviews were elaborated based on Science Motivation Questionnaire of Glynn *et al.* (2009) with specific questions about intrinsic motivation, self-determination, self-efficacy, career motivation and grade motivation. Students and teachers were also asked about the resources of the school and family support.

Interviews with the students at the school lasted around 20 minutes. With the teachers the interviews lasted around 40 minutes and occurred during free time or in the Collective Pedagogical Work Class. In total, 9, 7 and 12 students from schools A, B and C, respectively participated in the interviews. These numbers exceeded 10% of the total sample as recommended by Fraser and Gondim (2004) for qualitative research. Each student had the opportunity to participate during 2016 in four interactive lectures of about 75 minutes each. At the end of the first and third lectures, students returned to school, while at the end of the second and fourth lectures, they stayed for a snack and a visit at the museum and research laboratories of the university, respectively. IMI was applied after each of the four lectures before the students returned to school. The interviews were held at the end of the year of 2016.

Data analysis

To analyze the results of the questionnaires, descriptive statistics were used from the extraction of means, medians and standard deviations of each variable according to Chumbley *et al.* (2015). The software used was SPSS 17.0 and Microsoft Excel 2013. The interviews were recorded and later transcribed. For the qualitative analysis, they were read, followed by the separation of the sections that correspond to or permeate the questionnaire factors. The organization of the responses in categories that emerged from the interview and IMI analysis allowed discussion on how much the lectures contributed to the motivation to learn chemistry.

Students were identified according to the school. Students from School A were identified by SA1, from School B by SB1 and from School C by SC1 and so on. The teachers of School A, B and C were identified by "Teacher A", "Teacher B" and "Teacher C", respectively.

Results

IMI analysis

In the present study, for each lecture applied, Cronbach's alpha coefficient ranged from 0.82 (n = 110) to 0.85 (n = 154) indicating good internal consistency. In the study by McAuley *et al.* (1989) and Gerstner and Bogner (2010) values were equal to 0.85 and 0.67, respectively. By grouping all schools, the satisfaction of the motivational factors in each lecture is shown in Figure 1.

The questionnaire has a Likert scale of 5 points classified between 1 and 5, with the midpoint of the scale being 3. The analysis by lecture revealed a tendency to satisfy all the factors. In general, the *interest* and *value* factors presented medians close to 4.00 in all the lectures, which is equivalent to saying that the students "partially agreed" with the items relating to these factors. The *effort* factor was the one that presented the most variations throughout the presentations. The *perceived competence* factor presented a median of 3.00 indicating that students "do not know" about how competent they feel. The *pressure* factor was the least identified by the students in the lectures and presented a median of 2.25 in P2 alone, revealing that they "partially disagree" about feeling tense or pressured. In contrast to the pressure factor, the *perceived choice factor*, related to the satisfaction of autonomy presented the highest score - "totally agree".

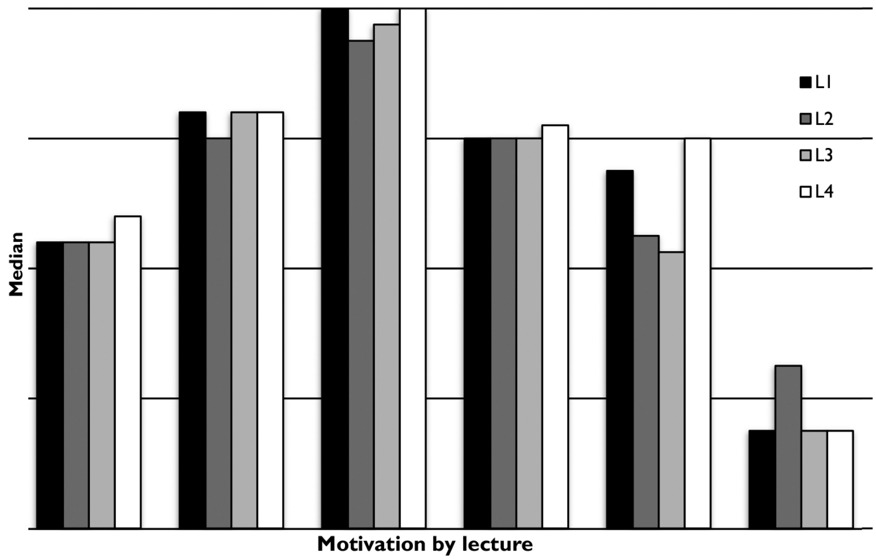

Figure 1: Histogram of motivation by lecture according to the medians.

Interviews analysis

Understanding the intrinsic motivation

When asked about the perceived changes in interest, pleasure or curiosity about chemistry after participation in three or four interactive lectures, 6 students responded that they did not observe any change and 22 responded that interest and curiosity increased.

The analysis resulted in the categories in which the students: (1) Started to have the will to know more; (2) Started to observe chemistry on a daily basis; (3) Started to have specific curiosity for the lectures; (4) Started to pay more attention in the classroom; (5) Started to perform other activities; (6) Started to study at home; (7) Others: answers that students did not know, could not justify or focused on increasing interest in different areas of chemistry; (8) Never been interested in chemistry and (9) Always been interested in chemistry. Table 2 shows the frequency of each category.

As an example of the categories (1) and (3), the speech of the student SA9 is presented below:

A: They changed because, as I said, I was more comfortable with the subject, right? I have more fun. In the classroom, I take it more seriously because you have to learn about the subject, but at home you have several videos, for example, on Youtube, that teach you how to make soap, those things that use chemistry.

Q: Did you do that before the lectures?

A: No. I did not like anything that was related to chemistry. It was in the middle of the first lecture, because they were showing the benefits that chemistry brings to society, so I started to like it (SA9).

At category (2), student SB5 said:

A: I started to understand more about chemistry, I started to want to study chemistry. For example, I am going to the gym and the knowledge that I have of chemistry, I go on to look at all the nutrients that supplements have. If I go to the market to buy Coca-Cola, I will take another look at Coca-Cola. I mean, Coca-Cola is not good because it has this and that. So, everything, everything I try to look at the packaging to know exactly what it has. I used to be interested, but I did not get excited. (SB5).

Table 2: Categories and frequencies of the answers according to the question "Do you believe that your pleasure, interest and curiosity about chemistry have changed after attending three or four lectures? How was this change?"

Intrinsic motivation	Distribution by school (%)	Category	Frequency* (%)	Number of citations
Increased (n=22)	A = 66.67 B = 85.71 C = 83.33	1	46.43	13
		2	14.29	4
		3	10.71	3
		4	7.14	2
		5	7.14	2
		6	3.57	1
		7	7.14	2
Remained the same (n=6)	A = 33.33 B = 14.29 C = 16.67	8	17.86	5
		9	3.57	1

*the answers may have been distributed in more than 1 category, so the sum of the frequencies is different from 100%.

Concerning the changes in interest, the three teachers mentioned the fact that the lectures had taken place outside of school as fundamental to arouse students' attention and change their behavior. Teacher C highlights the differences between the lectures and the classroom routine:

A: In the lectures we were out of the room doing an inquiry and experimental activity and the classroom involves a more theoretical content, sometimes heavier, so they have attention, but it is different. In the classroom, they pay attention at the moment they need to work out an exercise. I have to explain and they will understand the reasoning. In the lecture everything happens more spontaneously. They want to know more because of the curiosity they have. At school, I have to conduct because the content is sometimes more theoretical, heavier, more exhausting.

Understanding the self-determination

When asked about the perceived changes in the study and effort to learn chemistry after the interactive lectures, 12 students responded that they did not observe any change and 16 responded that interest and curiosity have increased.

The analysis resulted in the categories in which the students: (1) Started to study more out of school; (2) Started to develop activities at school more willingly; (3) Started to relate the lectures to the content of the school; (4) Started to talk to other people about chemistry; (5) Others: answers in which students did not know, did not remember, could not justify; (6) Always struggled to learn; (7) Never struggled to learn. Table 3 shows the categories and frequencies of these responses.

As an example of the categories (1) and (2), the student SA9 replied the following when asked about if the lectures of chemistry helped him to study and to put more effort:

A: Yes, because it gave me a certain interest to learn more and more. So instead of not liking it and doing nothing, I began to study.

Q: And how do you know you're more interested?

A: Because before the lecture I thought that chemistry was any other discipline to move on to the next grade, right? But after the lecture, we see that chemistry is cool for so many aspects of society.

Q: And what are you doing differently now?

A: Every lesson that the teacher spends in the classroom, instead of answering carelessly, if I do not know, I get home, I search and I answer the right way. I try to decorate the formula if I have to.

Q: And before did you do that?

A: No, I used to do it anyway.

Understanding the career motivation

When questioned about how much interactive lectures participation had influenced career choice, 19 students said that nothing has changed. Another 9 students claimed that they came to understand the benefits of chemistry for their professional careers after the lectures, as we can see in Table 4.

In the emerging categories, the students: (1) Do not see the relationship between chemistry and their future career; (2) Did not decide the professional career; (3) Always understood

Table 3: Categories and frequencies of the answers according to the question "Did the chemistry lectures help you study and make more effort after participate of three or four lectures? How?"

Self-determination	Distribution by school (%)	Category	Frequency*(%)	Number of citations
Yes (n=16)	A = 44.44 B = 85.71 C = 50.00	1	35.71	10
		2	32.14	9
		3	7.14	2
		4	3.57	1
		5	3.57	1
No (n=12)	A = 55.56 B = 14.29 C = 50.00	6	28.56	10
		7	7.14	2

*the answers may have been distributed in more than 1 category, so the sum of the frequencies is different from 100%.

Table 4: Categories and frequencies of the answers according to the question "About the benefits that chemistry can bring to your career, do you think differently after participation of three or four lectures? What has changed?

Career motivation	Distribution by school (%)	Category	Frequency* (%)	Number of citations
No (n=19)	A = 66.67	1	28.57	8
	B = 28.57	2	21.43	6
	C = 91.67	3	17.86	5
Yes (n=9)	A = 33.33 B = 71.43 C = 8.33	4	32.14	9

the relationship between chemistry and their future career; (4) Began to understand the relationship between chemistry and their future career.

As shown in the examples below, some students relate the importance of learning chemistry and their future career:

A: Because I think it will be important for my career in the future, since I intend to study medicine. I think that knowing a little more chemistry, deepening knowledge in chemistry, I think it will help me a lot in the future. (SB4).

And still in:

A: Oh, I would like to be a mechanic. Q: And do you think chemistry has anything to do with mechanics? A: I think so, such as welding material and dilution of solvents. I think it has chemistry. (SA7).

Understanding the self-efficacy

Student questioning about self-efficacy revealed that 20 students said they were more confident and 8 equally confident. Among those who said they were more confident, eight students attributed to better understanding of chemical concepts, six to better understanding about the nature of chemistry, five to increased learning effort, and three to increased interest. Among the students' statements, it is possible to observe evidence of the increase in self-efficacy attributed by the students to the participation of the interactive lecture.

When questioned about the feeling of competence for the learning of chemistry, the student SA7 pointed out that through the lecture he felt the improvement of his understanding on the chemical concepts:

A: The class has changed and I have seen that I can understand and interpret. But the teacher did not change the class, it was the lecture that changed me because I understood and did the exercise in the classroom.

Student SB3, however, showed a better understanding of the nature of chemical knowledge as it is possible to observe in:

A: Chemistry is not so complicated.

On the nature of scientific knowledge, Teacher C commented:

A: Knowing who does the research, that the scientist is not that guy who lives alone. You're tired of saying that anyone can do science, anyone can do research, right? They can understand that they are capable, that chemistry is not rocket science, so much that they solved some things, curiosity helped a lot.

The SC10 student feels more confident because he has observed both increased effort and interest:

A: I attended the lectures, I saw the university, I paid attention and thought that I want this for me. It makes you want to learn more and study hard.

Understanding the grade motivation

The evaluation of the grade motivation revealed that the majority (n = 19) did not observe changes and among them, 16 students remained concerned about the school grades. Among those who said they had changed their perception, four students were even more concerned and only one felt less concerned than before, as seen in Table 5:

Through the responses of the students it is possible to observe the maintenance of the concern with the grade at the end of the year:

A: I've always been concerned about grades. I think I am the same way (SC12).

Even when the student became interested in chemistry and tried harder to learn, the concern with the grade was maintained, as it is possible to observe in:

A: Oh, to move on to the next grade and not repeat a grade, I am the same way because before I was concerned. The only thing that changed was that in chemistry I usually studied just for the sake of studying. So after I had this bigger contact, I study and I know I am going to make a bigger result because I know I had learned. (SB5).

About the grade motivation, Teacher A pointed out that at school:

A: Their priority is to get the grades; their priority is the move on to the next grade. So they will adapt accordingly to it. "If I do the exercise, I get a good grade. So, I'm going to do the exercise". I believe they had a great time going out of school. Um ... you do not have an obligation to get right, to err, to be evaluated. So, these things contribute.

Only two students said they did not receive support from their parents to study. On the other hand, some students also complained of the pressure they suffer at home to take good grades, as in:

Table 5: Categories and frequencies of the answers according to the question "Was the concern about the extra grade, rewards, and scores changed after participation of three or four lectures? How was this change?"

Grade motivation	Distribution by school (%)	Category	Frequency* (%)	Number of citations
No (n=19)	A = 66.67 B = 80.00 C = 90.00	Still concerned Still unconcerned	66.67 12.5	16 3
Yes (n=5)	A = 33.33 B = 20.00 C = 10.00	Became more concerned Became less concerned	16.67 4.17	4 1

*the total of interviewees is 24 because the question was not asked for 4 students.

A: Oh, they give a lot of support, like, "If you do not do well at school, I will get your videogame or take your things, you will not be able to call anyone to come and play with you." They encourage me to come to school, like this (SA1).

Students' contact with the museum and the public university

The students' perception and interest in attending interactive lectures out-of-school were investigated. For this, the students were asked if they believed that it would be different to participate in the lectures in the school.

The students said it would be different because the museum environment is new to them, fun and allows students to express themselves differently. As an example, the student SB7 replied:

A: I think the museum is more interesting because you see things. There is a big screen as soon as they explain, if you do not know they will tell you again and you do an experiment there, something we do not do here at school. I think it is better there (SB7).

Concerning the approximation between university and school, Teacher A also commented on the enthusiasm of the students that was greater with the university than with the museum:

What I understood from the chemistry lecture was this relationship between the university, the people's day-to-day research, and the school. So, I think in that sense the lectures completed the goal, right? Because it was important for me too to know the research and also for the university to show itself to school, right?

Teacher C also commented:

I participated because, first, I like the methodology that was applied. Because it was very positive for me, right? So it is a way for them to have that close contact, but they understood that it is possible. That scientific research was shown to them differently from what they see on TV. It was shown by people doing the research; they are researchers who show the value of our city. This was essential to me, very important. Do you understand? For me, no other activity, at least that I experienced, came to show this so directly.

Discussion and conclusions

The IMI showed that all lectures met factors such as interest, perceived choice and competence, effort, value as opposed to the feeling of pressure that was the least punctuated, that is, it was not perceived by the students, as expected. The contentment of these factors confirms the potential of the interactive lectures to promote self-regulation for chemistry learning, so that the context in which they are applied is the main aspect to be taken into account. According to Berbel (2011), the use of active methodologies, by promoting the autonomy of the student, allows their involvement in the training process itself and the re-signification of their findings.

The highest score of the perceived choice factor as opposed to the pressure factor are indications of the promotion of the autonomy perceived by the students. The attribution of value to chemistry through the interactive lectures is fundamental to trigger a series of self-regulated behaviors for the learning of this science. According to Schunk (2012), linking learning to real world phenomena improves the perception of value that, in turn, precedes achievement, persistence, choice and also is related to self-observation, self-assessment, and goal setting. The self-efficacy factor was the least punctuated among the motivational components. The theory points out that this belief is dependent on specific domains, areas, or tasks, and in the present case, students are unaware of their competence to believe they do well when attending chemistry lectures (Parra and Kasseboehmer, 2018).

In the interview, the main category of intrinsic motivation in which students "started to have the will to know more" points to the increase of this motivation, since it is not determined by punishments or external rewards, but mainly by the interest and pleasure in knowing and learning of their own volition. Moreover, the "started to have specific curiosity for the lectures" category revealed signs of elevated situational interest (Lepper *et al.*, 2005). Although it is based on a transient occurrence, situational interest has the potential to develop long-term personal interest even in students who have little or no pre-existing interest in a subject (Hidi and Harackiewicz, 2000).

The two main categories of self-determination indicate effort, persistence and orientation towards learning. When learning-oriented, the quest for challenges may not be met in school, and the student uses other strategies to achieve it. According to Dweck and Leggett (1988), effort per se can be a source of pride, and the greater the degree of effort individuals perceive to have exerted, the greater is satisfaction and pride experienced. Husman and Lens (1999) also discuss the importance of the perception about the utility or instrumentality of certain activities in the present for the achievement of future goals considered valuable. Such perception, considered as an extrinsic motivation, influences aspects such as increased performance and self-determination. Thus, the understanding that chemistry learning will bring some benefit to the future can be a motivating factor for increased effort and the search for learning strategies.

The perception of utility and importance for the future is related to career motivation. It is important to emphasize that, often in adolescence the definition of the professional career includes doubts and uncertainties. Nevertheless, the exploration of this aspect, even if it is provisional, is important for understanding the possible relations between career motivation, as a form of more internalized extrinsic motivation, and motivation to learn chemistry. Students can have multiple goals and motivations to engage in learning. Husman and Lens (1999) argue that beyond these objectives being intrinsic and extrinsic, they can also be immediate or future, and the career motivation is related to the future perspective of the young.

The analysis of what students think about their future careers provides insight into how they can persist and be satisfied with the goals and tasks of the present. Students, designing their future careers, have stated that they believe that learning chemistry is beneficial to achieving their goals. This result indicates a more contextualized view of chemistry.

Vaino *et al.* (2012) discuss the importance of "personalizing" the learning situation by making clear to students the relevance of the topic addressed and relating the science learning to students' future. These aspects permeated the lectures and the themes of the research turn to environmental, economic, industrial interests, health, among others, that are beneficial to the community. When perceived by the students, these aspects contribute to the valorization of chemistry and the self-regulation of learning through more autonomous forms of extrinsic motivation. A key aspect of the interactive lecture was that the presentations were also made by chemistry undergraduates as scientific communicators. They had already studied in public schools and were able to share their experiences and present the scholarships. This enabled belief in the student's own ability. In most cases, it was the first time public school students came into contact with a science museum and a public university. In the case of the university, the contact of students from public schools with the routine of undergraduates, researchers and common technologies at university diminishes the distorted visions about what the university is and raises the interest for the learning of chemistry. For Illingworth *et al.* (2015) these events function as a kind of sowing, which the university cannot perform sporadically, given its importance.

With respect to the increase of grade motivation, the analysis of the justifications for the changes revealed a complex picture regarding the rewards. Most of the students remained concerned about the grades even though they felt more confident and interested in chemistry. According to Husman and Lens (1999), students' motivation is a result of the combination of intrinsic and extrinsic motivation. In a study about science motivation, Glynn *et al.* (2009) observed the preoccupation of many students with grades. It should also be emphasized that the school system preserves external regulations for the evaluation and classification of performance (Shachar and Fischer, 2004). Moreover, it is possible to observe that the family also plays an important role in external regulations when parents or guardians punish their children if they do not show good grades.

The aim of this study was to evaluate whether chemistry interactive lectures could contribute to the motivation to learn chemistry. The observation that part of the students began to study on their own initiative and use strategies chosen by themselves can be analyzed as a positive result and indicate that the participation of the interactive lectures contributed to the interest in chemistry and the choice of an action plan for its learning.

This research has important implications for the science popularization regarding the use of SDT as a theoretical basis for the study of motivation from an intervention planned and executed by the public university. As highlighted by Appel-Silva *et al.* (2010), Brazil does not have specific lines of study involving SDT, and there are few studies that propose interventions with this approach in addition to diagnosis. Therefore, the present study is expected to contribute to the advancement of this area.

Limitations and directions for future research

In this study, research in the area of chemistry showed to be a topic with motivational potential, given the relevance and proximity of the regional issues experienced by the students.

As some limitations, during the research the school's teachers were free to choose how to proceed and not even change the way they teach and interact with students. Thus, it is not possible to attribute the results exclusively to the interactive lectures. The motivating or even the controlling role of the teacher throughout the research also impacts on student motivation. Students' concern with the grades results from a number of aspects such as the school system, family attitudes, student orientation for performance, and what the student understands about external rewards grades and the desire to learn. These factors point to limitations of this study and to the need for investigations. The intervention and follow-up were carried out within a period of one year. Thus, it is important to understand the benefits and the longitudinal impacts of this practice in the long term. Within the scope of the partnership between universities and public schools, it is important to continue training teachers in the area of chemistry with a motivational style that promotes student autonomy. Besides the contact with the university, students' basic psychological needs will be nurtured. In addition, research can focus on girls' motivation to learn chemistry, which generally has low university entrance rates and high dropout rates. Another fundamental and uncommon aspect in Brazil was the formation of a research group with scientific communicators that belongs to the university and is directly connected to other researchers. Few researchers get closer to school students. Thus, future studies should seek ways for researchers to understand the importance of interacting with society and to become more actively involved in this process.

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