JOURNAL OF CHEMICAL EDUCATION

Open Access

pubs.acs.org/jchemeduc

Article

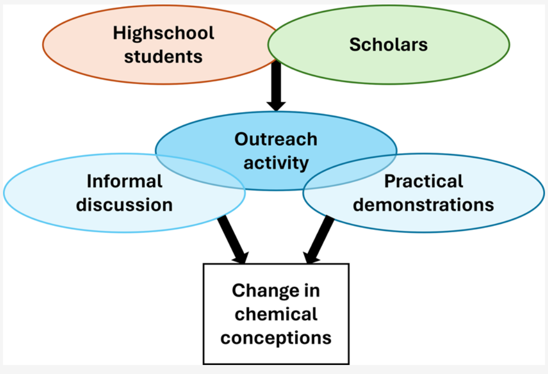
Effect of Science Outreach Activities on Chemophobic Conceptions at the High School Level

Roberto Sáez-Hernández* and Rafael Ballesteros-Garrido

Cite This: *J. Chem. Educ.* 2024, 101, 1635−1641

Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information



ABSTRACT: Chemophobia is a widely spread phenomenon in all strata of society, including high school students. Like adults, teenagers are exposed to the same environment and information sources that infuse an irrational fear toward chemistry and its influence in our society. The potential harm that hesitant positions against chemistry can have among the general public is sustained by the existing scientific literature, indicating that these positions are often based on wrong conceptions. This creates an urge to develop new approaches to counteract chemophobia among the general public and students in particular. Given the fact that secondary students are still in a learning stage, intervening at these early moments is a potential dissemination strategy. In this work, the influence of science outreach activities carried out by scholars at compulsory (aged 14−15) and pre-university (aged 17−18) levels is assessed in terms of chemophobic conceptions. To measure the shift in their conceptions, students answer questions before and after the activity. Results indicate that compulsory students are slightly more predisposed to have chemophobic conceptions than pre-university students. After the activity, the post-conceptions of both groups significantly changed regarding some topics, moving toward more receptive positions about chemistry. This effect was more evident among pre-university students, probably due to their stronger prior scientific backgrounds. Overall, this work presents evidence for the potential that science outreach activities have in fighting chemophobia at lower education levels.

KEYWORDS: *High School, Demonstrations, Public Understanding/Outreach, Misconceptions, Nonmajor Courses*

■ INTRODUCTION

A quick search of the Oxford dictionary or the Spanish Royal Academy of the term "chemophobia" does not yield any definition of the concept. Hence, researchers have needed to come up with a definition of such a concept with all the challenges that come with it. In this work, we will align with the definition given by Saleh et al.,[1] which states that "chemophobia is the irrational fear of chemicals", as it very simply describes what the authors understand about chemophobia. This definition also allows one to work on a conceptual frame that, from the point of view of the authors, helps to distinguish between justified fear of chemicals and the nonjustified (that is, irrational) reluctance toward chemistry.

The origin of chemophobia is often attributed to the lack of knowledge about chemistry but, at the same time, to an excess of information.[2] This, despite seeming contradictory, is explained on the basis that an overwhelming amount of information is often not trustworthy, and many times, it is flawed or skewed to a certain chemophobic perspective. As a consequence, a wide public is exposed to a very significant number of sources that usually transmit chemophobic messages, either explicitly or subtly. This public has a tendency to lack the skills needed to rationally analyze and interpret them. This being said, it should be noted that chemistry, as wide and varied as it is, occasionally deals with highly concerning, toxic, and harmful compounds, so certain fears and precautions are justified in these contexts. For example, in cases of accidents or bad practices, hazardous chemicals have created actual harm to some populations. Also, the case of environmental pollution represents an example of justified fear toward the presence of certain chemicals. In these instances, a concern toward chemical compounds is legitimate, as they can become a hazard to the well-being of individuals. Nevertheless, there are some other examples in which some people reject any chemistry-related topic regardless of the context. Thus, one needs to find a balanced point based on rational thinking and knowledge. In summary, in this article the authors will address the proposed activity as a tool to study and fight the irrational rejection of anything related to chemistry (i.e., chemophobia)

Received: January 22, 2024
Revised: February 27, 2024
Accepted: February 28, 2024
Published: March 11, 2024

while accepting that this irrational fear should not be confused with the necessary precautions that need to be taken when handling or legislating concerning or harmful chemicals.

The presence of chemophobia in our society is far from being innocuous. Chemistry has been key to the development of our society, and the well-being many of us enjoy has been provided to a great extent by chemical knowledge and its application. Among others, the literature shows that chemophobic conceptions are behind biased decision-making processes. For instance, there is a misjudgment of the risk associated with eco-friendly or nonchemical products,[3] and generally, "natural" foodstuffs are preferred over "chemical-containing" food.[4] Citizens guide their lives based on what they consider as truth and what is best for their interests, with this also being the case for health-related issues. If we take for granted that chemophobia is generally present in our society, we can also consider it as a factor influencing health-related decisions.[5]

Chemophobia in High Schools

As an extension of the context developed so far, the presence of chemophobia is also expected among high school students. Thus, it is of interest to investigate its presence in schools where the general population is trained and educated: schools and high schools. Based on the research of Belenguer-Sapiña et al.,[6] it was evidenced that students present chemophobic conceptions from a very early age, specifically in topics covering feeding and the presence of chemicals in food. In this context, one may ask what can be done in order to fight these concerning conceptions from the researchers' point of view.

Proposals to Fight Chemophobia

Different approaches have been proposed so far in order to tackle the chemophobic viewpoints that exist in our society. For example, Belenguer-Sapiña et al. suggested using chemophobia as a debate topic in class so that students can engage in a debate with the teacher about their different concerns.[6] This would contribute to some authors' opinions that state that communicating proper and correct chemical knowledge is the way to go when fighting chemophobia, for example, through educational books.[2] From another perspective, other authors propose that the lack of scientific (or, in this case, chemical) knowledge is not enough to justify the existence of chemophobia. According to this perspective, the social and cultural interactions that people build and use to process information highly influence their ability to modify and change thought patterns and processes. Following this idea, the fight against chemophobia should be guided by a personal interaction between the target audience and some information curators that they find credible and close to their standpoints.[7]

Some works have proposed using metaphors about chemical knowledge in order to talk about and fight chemophobia. In this sense, authors defend that each and every chemophobic conception should be discussed individually and patiently, as if designing a chelating compound for a target molecule.[3] Other approaches rely on the power of heroism in storytelling, proposing to communicate chemistry by enhancing the value of the chemists who work on it,[8] while the use of mass-media social platforms like YouTube has also been proposed as a potential tool to reach the public with messages fighting chemophobia.[9]

Overall, although lack of knowledge is not the only cause for chemophobia, it is an important factor when it comes to it spreading in our societies.[5] Since formal education, understood as the learning that takes places in educational facilities under a regulated program and curriculum, is one of the main sources of knowledge in European society, it becomes clear that the role of teachers and chemists is essential in order to influence the perception of chemistry among people.[2,3,6] More specifically, like George Porter stated more than 30 years ago, "we should refer back to schooling."[2,10]

The effect of scientific outreach activities on STEM (science, technology, engineering, and mathematics) literacy has been studied in the literature. For example, an online contact form to get in touch with scientists and scholars was valued as very helpful by teachers, and it was demonstrated to have a positive effect on both science literacy and the affective view of science.[11] Also, storytelling activities carried out in research facilities to children aged between 8 and 10 demonstrated that they could enjoy science-related activities from very early on.[12]

Hence, the development of outreach activities at this level can potentially have an impact on these wrong and harmful conceptions. Additionally, it has also been proposed that creating activities for students can also become useful if parents are encouraged to come with them, reaching a wider audience as a consequence.[13] Based on prior research, it has been demonstrated that communicating trustworthy information is a more effective way of fighting chemophobia when compared to methods based on feelings.[1]

Prior research has been published investigating the effect of informal conversation among high school students and scholars and researchers. However, the analysis was focused on its contribution to the general perception of students toward science, how scientific knowledge is developed, and their capacity of identifying science in our society.[14]

This work intends to shine a light on the influence that science outreach activities can have on high school and pre-university students' chemophobic conceptions. As Rollini et al. stated on their review, "researches on how to counteract chemophobia are scarcer than those that try to define and quantify it."[15] This review attempts to describe the potential that engaging with young students can have on their present chemical conceptions.

The objective of this article is to describe and measure the shift in students' perception toward chemistry after an outreach activity carried out by scholars in high school institutions. Based on Belenguer-Sapiña et al.'s work,[6] we will depart from the hypothesis that students are a part of society and are hence affected by the different chemophobic messages that circulate around it. Some prior and recent research has demonstrated that chemistry workshops carried out in a close relationship between the practitioner and the public help induce more receptive positions toward chemistry.[16] In this article, a survey of students' opinions on some topics (chemistry from a general perspective and its relationship with food, health, and cosmetics) is collected before and after a science dissemination activity is carried out in high schools. With it, statistical analysis of the results is investigated in order to check for significant changes in the students' conceptions toward some chemistry-related aspects.

■ METHODOLOGY

Activity

The outreach activity consists of a workshop carried out by young researchers, Ph.D. students, and faculty (professors) from the Faculty of Chemistry in different high schools. The

https://doi.org/10.1021/acs.jchemed.4c00074
J. Chem. Educ. 2024, 101, 1635−1641

activity was split into two parts: first, an informal introduction talking about chemistry and its involvement in daily life and second, a practical workshop in which different demonstrations were carried out.

Regarding the first part, the objective of which is to serve as an introduction, different topics are addressed by adapting the contents to the public target. More specifically, topics like food additives, components, medical and pharmaceutical active principles, or the rationale behind sunscreen are explained. These are selected because they are recognizable by the students, who can gain an understanding of the degree of involvement of chemistry in their daily lives. In this paper, some examples of chemophobic messages and strategies are shown.

In the second part, some practical demonstrations are carried out to visualize some eye-catching reactions: phenolphthalein color change with NaOH; a "blue bottle" involving a redox reaction between oxygen and glucose, which is reflected on the color of methylene blue; complex formation between Cu and ammonia; or a "soap volcano" using hydrogen peroxide, iodine, soap, and food colorant. Also, the concept of pH is demonstrated with red cabbage extract and different known solutions: HCl, $NaHCO_3$, bleach, lemon juice, etc. These demonstrations are very simple, safe, and eye-catching. In each one of them, the relationship between these reactions and some known examples is emphasized in order to bring closer the chemical knowledge to their realities. See the Supporting Information for a more detailed description of the outreach activity.

Questionnaire Description

The form consisted of two separated parts: first, a section devoted to data collection regarding sample description (age, gender, course, and academic path) and second, a section including the different questions. In this second section, 25 questions based on the research published by Belenguer-Sapiña et al.[6] are stated. Each question allowed for a selection among six options, ranging from "strongly disagree" to "strongly agree", and no mid-option was considered.

The rationale behind this selection is that this study aimed to capture the conceptions of students about chemistry, and hence, having a midpoint option could mean that, in the case of not knowing the "true answer", students could rely on the most comfortable option, which would be to not answer or place themselves in the middle.[17]

The inclusion of six possible answers was designed to capture more subtle changes in the opinions of students about the different topics. Since the midpoint option had been discarded, the number of possible answers had to be even, so two main options were considered: having four or six available responses. In this work, six was selected rather than four in order to have a clearer perspective on the investigated topics; with only four options (which would have been from a very negative position to a negative, positive and very positive conception), students would be forced to fit within a category which might not represent their actual point of view. However, having six possible answers allows for better representativity of the responses, as it is more possible that students find an answer that suits their opinion.[18]

Hence, the gradient from the most negative option to the most favorable answer was as follows: strongly disagree ("1"), disagree, partially disagree, partially agree, agree, and strongly agree ("6"). In Table 1, descriptions of the questions included in the work are displayed. Two control questions were included, which explicitly asked for the selection of one specific answer in order to filter forms that had been randomly filled. The question form was completed online in an anonymous way.

Table 1. Question Form Distributed to the Students[a]

Code	Question
Q1	Chemistry is a dangerous science for society
Q2	Our society's well-being is not related to chemical knowledge and development
Q3	During this day I have not used any chemical product
Q4	The increase of illnesses nowadays is caused by the presence of chemical products in the environment
Q5	Natural foodstuffs do not contain chemical products
Q6	The presence of chemical products in foodstuffs can generate health problems
Q7	The intake of pesticides in crops is dangerous
Q8	The presence of antibiotics in meat is a danger for the health of the population
Q9	There are not chemical products in natural foodstuffs and products
Q10	An organic product is healthier than a conventional one
Q11	It is preferable to consume products that are free of chemicals
Q12	Naturally present colorants are healthier than artificial ones
Q13	It is preferable that foodstuffs contain biological components instead of chemical products
CQ1	Please, click on the option "strongly agree"
Q14	I prefer to pay more for a natural product than for an artificial one
Q15	Foodstuffs considered as "local products" do not contain added chemicals and are therefore more recommendable
Q16	Natural products have better organoleptic properties: flavor, smell...
Q17	Natural remedies are preferable over conventional medicines
Q18	An active principle obtained from plants is more recommendable than one obtained through synthesis processes
Q19	Alternative medicine is more recommendable because it does not employ pharmaceuticals
Q20	Natural remedies do not imply any hazards or generate secondary effects
Q21	Cosmetics made from natural products are more effective
CQ2	Please, click on the option "agree"
Q22	Shower soaps that are "free of sulfates" are better suited for the skin than ones that do contain sulfates
Q23	Shower soap with "neutral pH" is better because it respects the natural pH of the skin
Q24	I prefer using a shampoo that is free of parabens rather than one that does not indicate anything about it
Q25	The absence of chemical products in natural cosmetics justifies their higher price

[a]Allowed answers ranged from "strongly disagree" to "strongly agree" in a six-option scale. Two control questions were included to remove answers randomly filled.

As can be observed, questions can be classified into four main groups: Q1−Q4 are questions related to the general influence of chemistry in today's world. Q5−Q16 are questions about chemistry in foodstuffs. Q17−Q20 ask about chemistry in medicine, and lastly, Q21−Q25 are focused on chemistry and cosmetics. Additionally, all the questions were phrased so that low values in the responses reflected low chemophobic conceptions, while higher values would mean a more negative perception toward chemistry. This way, results can be homogeneously interpreted throughout the paper.

The questionnaire was sent in advance to the high school teachers for them to disseminate it among the students, collecting the pre-responses. Next, after the activity was carried out, the question form was left open for several months for the students to freely respond to it when possible.

https://doi.org/10.1021/acs.jchemed.4c00074
J. Chem. Educ. 2024, 101, 1635−1641

The question form was carried out online through the University of Valencia virtual tool, ensuring data protection and confidentiality. No personal information that could be traced back to the identities of the students was gathered during the sampling. The activity and data collection are supported and endorsed by the Faculty of Chemistry, and the question form was sent to the different high schools in advance to grant their permission.

Statistical Comparison

Data was analyzed using R.[19] In order to compare the pre- and post-activity results, the Wilcoxon test was used. This method was selected because the data did not follow a normal distribution in some instances. As a nonparametric method, the Wilcoxon test does not rely on any particular data distribution[20] and, thus, allows one to draw sound conclusions in a rigorous way.

■ RESULTS AND DISCUSSION

In this section, the results gathered for the student's sample are assessed. First, an investigation into the prior state is performed in order to capture the starting point of their chemistry-related conceptions. Second, the change between the initial and final states is studied. At that point, the influence of the workshop is assessed.

Sample

The students belonged to two different high schools in the metropolitan area of the Valencia (Spain) region, both of them belonging to the public educational system. Two different courses, both offered at the studied high schools, were taken into account. The first was students enrolled in the subject "Physics and Chemistry", which belongs to the Spanish compulsory secondary education curriculum and is taught in the third (out of four) year of compulsory education (coded as "compulsory"). The second was pre-university students enrolled in the subject "Chemistry", coursing the last year of noncompulsory education before entering college (coded as "uni-prep"). As per the composition of the classes, the sample is described in Table 2.

It must be considered that there are some limitations regarding the data set presented in this paper. First, the geographical aspect: data were collected from two high schools in the Valencian metropolitan area (Spain). Thus, students are enrolled in a certain education system that influences their learning. Also, the students' knowledge and competency will depend on their background and academic experience, such as, for example, prior teachers. Finally, it must be taken into account that a drop in the number of responses was observed in the post-stage compared to the pre-stage. This happened especially with female students.

Table 2. Sample Description[a]

Course	State	Gender	Number of Responses
Compulsory (aged 14−15)	Initial	Boy	23
		Girl	21
		Not disclosed	2
	Posterior	Boy	12
		Girl	7
		Not disclosed	3
Uni-prep (aged 17−18)	Initial	Boy	27
		Girl	26
		Not disclosed	6
	Posterior	Boy	19
		Girl	6
		Not disclosed	2

[a]Two courses were addressed: a compulsory one (subject "Physics and Chemistry") and a pre-university one (subject "Chemistry").

Prior Conceptions among Secondary Students

At this point, the values regarding the different questions are assessed to have an outlook of the prior conceptions of secondary and pre-university students. Results of the a priori conceptions of students are reflected in Supporting Table 2. In the table, the results obtained for the scores are presented, along with the confidence interval (CI) at 95% probability. Also, the p-values for the comparison between both courses are shown (computed using the Wilcoxon test).

As a general trend, results from both courses are very similar to each other, except for the case of some specific questions (Q5 and Q9), which show a lower chemophobic conception of pre-university students. As can be seen in Table 1, these two questions are very similar to each other and were rephrased to check the coherence of the answers. This would point to a more precise knowledge about the term "chemical compound" among the pre-university students. Furthermore, questions Q16 and Q21 also presented statistically significant differences between courses. Both questions refer to supposedly better properties of natural products over their equivalent synthetic ones, more specifically in the sense of their organoleptic properties (Q16) and their effectiveness in cosmetics. As seen in Supporting Table 2, pre-uni students demonstrate lower levels of reticence toward chemistry, likely due to their more sophisticated knowledge of the field.

Assessing the results per topic, values below 3.5 could be considered as "low chemophobia", while results above that threshold could be understood as "high chemophobia". Results indicate that , regardless of the course, questions regarding general perception toward chemistry are considered with low chemophobic opinion, as well as considerations about chemistry in medicine (except for Q18, which is found in the intersection for both courses). However, it is interesting to see that questions about chemistry in foodstuffs and cosmetics are generally seen from a chemophobic point of view.

These results are in good accordance with those previously presented by Belenguer-Sapiña et al. for high school students,[6] implying that while students have certain chemophobic conceptions that reflect higher scores for feeding and cosmetic questions, they are still able to recognize the importance of chemistry to our society, scoring lower in the "general" set of questions. Results about the negative perception of chemistry in food-related aspects have previously been assessed among the general population.[5,21,22] As for the questions regarding cosmetics, less literature is found; however, it can be concluded that there exists a fear toward chemical compounds present in such products.[23,24]

In brief, the results of the "before" state further corroborate those presented for high school students and follow the general trend of our societies. Thus, it is encouraging to develop strategies to change those conceptions.

Change in Conceptions after the Activity

In this section, the effect of the outreach activity is assessed based on the same question form that was completed after the

Table 3. Comparison of Pre- and Post-States[a]

	Compulsory Course			Pre-Uni Course		
	Mean ± CI (95%)			Mean ± CI (95%)		
Question	Before	After	*p*-Value	Before	After	*p*-Value
Q1	2.4 ± 0.3	2.1 ± 0.4	0.4	2.08 ± 0.23	2.2 ± 0.3	0.6
Q2	2.5 ± 0.3	2.4 ± 0.5	0.8	2.2 ± 0.3	2.4 ± 0.5	0.9
Q3	2.9 ± 0.5	3.1 ± 0.7	0.9	2.8 ± 0.4	1.37 ± 0.19	*0.003
Q4	3.5 ± 0.3	3.2 ± 0.6	0.5	3.5 ± 0.3	2.7 ± 0.3	*0.003
Q5	3.6 ± 0.4	3.6 ± 0.6	0.9	2.8 ± 0.3	1.9 ± 0.3	*0.007
Q6	4.2 ± 0.3	3.8 ± 0.5	0.25	4.46 ± 0.24	2.7 ± 0.4	*7×10^{-8}
Q7	3.9 ± 0.3	3.7 ± 0.5	0.6	4.42 ± 0.23	3.3 ± 0.4	*0.00012
Q8	3.6 ± 0.3	3.6 ± 0.6	0.9	4.1 ± 0.3	3.1 ± 0.4	*0.0017
Q9	3.2 ± 0.4	3.3 ± 0.5	0.6	2.29 ± 0.23	2.0 ± 0.4	0.10
Q10	4.3 ± 0.3	3.3 ± 0.4	*0.005	4.4 ± 0.3	3.0 ± 0.5	*0.00024
Q11	4.9 ± 0.3	4.0 ± 0.6	*0.03	4.97 ± 0.18	3.2 ± 0.4	*1.8×10^{-8}
Q12	4.5 ± 0.3	3.8 ± 0.5	*0.03	4.78 ± 0.24	3.4 ± 0.5	*6×10^{-5}
Q13	4.2 ± 0.3	4.0 ± 0.4	0.7	4.66 ± 0.20	3.3 ± 0.4	*5×10^{-6}
Q14	4.2 ± 0.3	3.4 ± 0.7	0.12	3.8 ± 0.3	2.4 ± 0.4	*5×10^{-5}
Q15	3.50 ± 0.22	3.2 ± 0.5	0.4	3.4 ± 0.3	3.0 ± 0.5	0.22
Q16	4.3 ± 0.4	3.5 ± 0.5	0.06	3.8 ± 0.3	3.1 ± 0.5	*0.04
Q17	3.2 ± 0.4	3.1 ± 0.5	0.8	3.2 ± 0.3	2.4 ± 0.5	*0.03
Q18	3.5 ± 0.3	3.4 ± 0.5	0.8	3.7 ± 0.3	2.3 ± 0.4	*2.5×10^{-5}
Q19	3.2 ± 0.3	3.2 ± 0.5	0.8	2.8 ± 0.3	2.1 ± 0.4	*0.020
Q20	2.9 ± 0.3	2.7 ± 0.5	0.4	2.8 ± 0.3	2.0 ± 0.5	*0.0022
Q21	3.8 ± 0.3	3.4 ± 0.5	0.3	3.3 ± 0.3	2.5 ± 0.4	*0.014
Q22	4.4 ± 0.3	3.8 ± 0.5	0.08	4.15 ± 0.23	3.3 ± 0.5	*0.008
Q23	4.1 ± 0.3	3.8 ± 0.5	0.5	4.49 ± 0.24	3.1 ± 0.6	*0.0024
Q24	3.7 ± 0.4	3.5 ± 0.6	0.6	3.93 ± 0.24	3.0 ± 0.4	*0.0015
Q25	3.8 ± 0.3	3.8 ± 0.5	0.8	4.0 ± 0.3	3.8 ± 0.6	0.7

[a]Results are expressed as the mean and confidence intervals (CI, 95%). An asterisk marks the questions for which the mean values of "before" and "after" are significantly different according to a Wilcoxon test (*p*-value < 0.05, two-tailed).

activity. Table 3 shows the obtained results for both courses before and after the activity.

At a first glance, it is observed that the results generally move toward lower scores, meaning that the conceptions of students changed in the direction of positions that are more receptive toward chemistry. This change is observed to a higher extent in the case of pre-university students, as average values change significantly in most of the questions, especially in those that were initially scoring higher in the scale.

Looking at the compulsory group, the effect seems important in some questions (Q10−Q12) given the statistically significant change observed between the initial and ulterior stages, which were topics explicitly treated in the workshop. When it comes to the rest of the questions, mean values generally move to lower values, but the confidence intervals before/after overlap at least partially in most of them. In this sense, according to the significance tests, only questions Q10−Q12 are demonstrated to have significant differences between the initial and final states. All three of these questions ask about similar topics: the presence of chemicals in food and the concept of "natural". Nonetheless, it must be considered that this shift toward more chemistry-receptive positions does still leave the score above 3.5, meaning that overall, there is still a somewhat skeptical orientation toward chemistry. Out of these three questions, only Q10 crosses the threshold value of 3.5, meaning that it goes from an average negative conception toward a positive one. This is also the case for Q21, regarding the effectiveness of cosmetics and their relationship with chemical compounds.

However, for pre-university students (uni-prep), the differences are much more marked, and questions Q3−Q8, Q10−Q14, and Q16−Q24 showed significant differences between the initial and final stages according to the analysis. As it is observed, questions regarding foodstuffs and cosmetics generally started at values above 3.5, but after the activity, they shifted to values below this threshold. This reflects a significant modification of the students' conceptions about chemistry and their relationship with these topics.

The difference between educational levels might be due to the different starting points of the students, according to a constructivist point of view:[16] while pre-university students present more advanced knowledge and mental schemes to build upon, compulsory students lack the proper prior knowledge to actually modify their conceptions about chemistry. This is reflected in the fact that secondary students modify their conceptions exclusively for the questions which were explicitly treated during the workshops, while pre-university students are able to extrapolate the discussed topics to other questions.

The importance of basic knowledge has been previously reported in the literature. For instance, chemophobia among college students was investigated, and a higher amount of chemical knowledge correlated negatively with the measured chemophobia.[25] In this work, these results are also evidenced at the high school level.

The results presented are promising, as they clearly demonstrate that students value the opinion of chemistry scholars as trustworthy when it comes to chemistry-related topics. This is present in the risk assessment literature as "trust

https://doi.org/10.1021/acs.jchemed.4c00074
J. Chem. Educ. 2024, 101, 1635−1641

heuristics": when needing to make a decision on a topic about which we lack sufficient information, we often rely on relevant stakeholders or personalities we consider competent in the matter.[5,7,26] However, as commented above, the importance of prior knowledge seems to play an important role in this sense, as pre-university students were more receptive to the message than high school students.

There exist some other factors to be taken into account when assessing the potential of this activity in modifying chemophobic conceptions among students. The first is a nonmeasurable one, but one that was noticed by the authors during the visits to high schools. Many times, when discussing with teachers, they transmit the opinion that "even though we can say the exact same thing as you did, students often overlook it." This effect has been also observed in other contexts and countries[11] and could potentially be attributed to the perception that students have toward the person speaking. In this way, a close and nonjudgmental attitude with the students is recommended based on our experience, which is shared with some prior examples.[16]

Second, the outreach activity serves as a catalyst to engage students in a conversation about topics that concern them. This strategy has been proposed as a good approach in order to gain a fundamental understanding on what interests they find important and what kind of questions or hesitations they have about chemistry-related topics.[14] Indeed, during the visits paid to high schools, the authors encountered the chance to talk about and discuss topics that students were curious about but did not bring up during their typical lessons. This links to the previous idea: even though they share daily contact with their chemistry teachers, they find an alternative way to solve their questions with these kinds of activities. Once again, the social aspect of science communication becomes important.[7]

All in all, these results point to the conclusion that, as chemical researchers, investing part of our time in disseminating science and chemistry among high school and pre-university students has an observable benefit on their conceptions toward chemistry. It means taking part in our society and helping chemistry teachers in their labor,[11] and it is aligned with the results of previous works that support the benefits of informal contact between chemists and students.[12] Additionally, the proposed activity suits the "5-E's principle" proposed by some authors,[24] in which it promotes educating, engaging, and entertaining students in order to fight chemophobia.

■ CONCLUSIONS

The results presented in this work demonstrate that outreach activities carried out by researchers in the high school level are a helpful tool that can modify chemophobic conceptions toward a more receptive and less reticent position when it comes to chemistry in our society. The differences found between pre-university and secondary students give an insight into the importance of prior knowledge when it comes to conceptual changes.

Hence, based on these results, outreach activities should be planned in advance depending on their main objective, taking into account the nature and profile of their audience. While the effectiveness of the activity on pre-university students seemed to be higher regarding chemophobia, it does not necessarily mean that secondary students did not receive any benefit from it: potentially, interest and motivation are susceptible of being improved, but their measurement was out of the scope of this work.

As was discussed in the text, the results presented in this context must be considered with the appropriate sampling limitations. The students represented in this work belong to two public high schools in the Valencian metropolitan area (Spain). Also, their academic backgrounds might be an influencing uncontrolled variable in this study. However, the data presented here allow us to objectively determine that scholar outreach activities in secondary teaching institutions help in modifying the conceptions that students own regarding chemistry and chemophobia.

Overall, this work demonstrates the importance of outreach and science dissemination among students during their compulsory and pre-university courses. It is well-known and illustrated by the literature that some agents instill chemophobic conceptions in society with different interests and that it has direct consequences in many aspects of our lives, from health to the economy. This is why scientific training and knowledge is a key part of their compulsory education, but sometimes, it is not enough. As some of the high school teachers have stated in private conversations during the activity, "We can make them notice, but there is no use, either because that information makes little impact on them or because they simply will not listen." This is why the proposed activity can be a handy complement to their otherwise crucial and valuable work.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.4c00074.

Description of the outreach activity, example of the survey, and supporting tables (PDF)

■ AUTHOR INFORMATION

Corresponding Author

Roberto Sáez-Hernández − *Department of Analytical Chemistry, Faculty of Chemistry, University of Valencia, Burjassot 46100, Spain*; Email: roberto.saez@uv.es

Author

Rafael Ballesteros-Garrido − *Department of Organic Chemistry, Faculty of Chemistry, University of Valencia, Burjassot 46100, Spain*; orcid.org/0000-0002-8364-114X

Complete contact information is available at:
https://pubs.acs.org/10.1021/acs.jchemed.4c00074

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

The authors thank the students and the teachers for their participation in the activity. R.S.-H. thanks the Spanish Ministry of Universities for the predoctoral position (FPU19/02304) and Ramón Ferri-García for his assessment and counseling.

REFERENCES

(1) Saleh, R.; Bearth, A.; Siegrist, M. Addressing Chemophobia: Informational versus Affect-Based Approaches. *Food Chem. Toxicol.* **2020**, *140*, 111390.
(2) Rulev, A. Chemical Education Contra Chemophobia. *CHIMIA* **2021**, *75* (1−2), 98−98.
(3) Chalupa, R.; Nesměrák, K. Chelation as a Metaphor for the Effective Fight against Chemophobia. *Monatshefte Für Chem. - Chem. Mon.* **2019**, *150* (9), 1585−1592.
(4) Dickson-Spillmann, M.; Siegrist, M.; Keller, C. Attitudes toward Chemicals Are Associated with Preference for Natural Food. *Food Quality and Preference.* **2011**, *22*, 149−156.
(5) Siegrist, M.; Bearth, A. Chemophobia in Europe and Reasons for Biased Risk Perceptions. *Nat. Chem.* **2019**, *11* (12), 1071−1072.
(6) Belenguer-Sapiña, C.; Briz-Redón, Á.; Domínguez-Sales, M. C. Do Social Chemophobic Attitudes Influence the Opinions of Secondary School Students? *J. Chem. Educ.* **2021**, *98* (7), 2176−2187.
(7) Francl, M. How to Counteract Chemophobia. *Nat. Chem.* **2013**, *5* (6), 439−440.
(8) Chalupa, R.; Nesměrák, K. Chemophobia versus the Identity of Chemists: Heroes of Chemistry as an Effective Communication Strategy. *Monatshefte Für Chem. - Chem. Mon.* **2020**, *151* (8), 1193−1201.
(9) Smith, D. K. iTube, YouTube, WeTube: Social Media Videos in Chemistry Education and Outreach. *J. Chem. Educ.* **2014**, *91* (10), 1594−1599.
(10) Freemantle, M. In *Chemistry in Action*; Macmillan, 1987.
(11) Kohen, Z.; Herscovitz, O.; Dori, Y. J. How to Promote Chemical Literacy? On-Line Question Posing and Communicating with Scientists. *Chem. Educ. Res. Pract.* **2020**, *21* (1), 250−266.
(12) Morais, C. Storytelling with Chemistry and Related Hands-On Activities: Informal Learning Experiences To Prevent "Chemophobia" and Promote Young Children's Scientific Literacy. *J. Chem. Educ.* **2015**, *92* (1), 58−65.
(13) Smith, R. B.; Karousos, N. G.; Cowham, E.; Davis, J.; Billington, S. Covert Approaches to Countering Adult Chemophobia. *J. Chem. Educ.* **2008**, *85* (3), 379.
(14) France, B.; Bay, J. L. Questions Students Ask: Bridging the Gap between Scientists and Students in a Research Institute Classroom. *Int. J. Sci. Educ.* **2010**, *32* (2), 173−194.
(15) Rollini, R.; Falciola, L.; Tortorella, S. Chemophobia: A Systematic Review. *Tetrahedron* **2022**, *113*, 132758.
(16) Palmer, A. L.; Sarju, J. P. Inclusive Outreach Activity Targeting Negative Alternate Conceptions of Chemistry. *J. Chem. Educ.* **2022**, *99* (5), 1827−1837.
(17) Croasmun, J. T.; Ostrom, L. Using Likert-Type Scales in the Social Sciences. *J. Adult Educ.* **2011**, *40* (1), 19−22.
(18) Joshi, A.; Kale, S.; Chandel, S.; Pal, D. Likert Scale: Explored and Explained. *Br. J. Appl. Sci. Technol.* **2015**, *7* (4), 396−403.
(19) R Core-Team. R: A Language and Environment for Statistical Computing. 2022. https://www.r-project.org/.
(20) DePuy, V.; Berger, V. W.; Zhou, Y. Wilcoxon-Mann-Whitney Test: Overview. In *Wiley StatsRef: Statistics Reference Online*; John Wiley & Sons, Ltd., 2014. DOI: 10.1002/9781118445112.stat06547.
(21) Román, S.; Sánchez-Siles, L. M.; Siegrist, M. The Importance of Food Naturalness for Consumers: Results of a Systematic Review. *Trends Food Sci. Technol.* **2017**, *67*, 44−57.
(22) Bearth, A.; Saleh, R.; Siegrist, M. Lay-People's Knowledge about Toxicology and Its Principles in Eight European Countries. *Food Chem. Toxicol.* **2019**, *131*, 110560.
(23) Lee, B.-M.; Kwon, S.; Cho, Y. M.; Kim, K.-B.; Seo, K.; Min, C. S.; Kim, K. Perspectives on Trace Chemical Safety and Chemophobia: Risk Communication and Risk Management. *J. Toxicol. Environ. Health A* **2019**, *82* (3), 186−199.
(24) Chalupa, R.; Nesměrák, K. Analytical Chemistry as a Tool for Suppressing Chemophobia: An Introduction to the 5E-Principle. *Monatshefte Für Chem. - Chem. Mon.* **2018**, *149* (9), 1527−1534.
(25) Eddy, R. M. Chemophobia in the College Classroom: Extent, Sources, and Student Characteristics. *J. Chem. Educ.* **2000**, *77* (4), 514.
(26) Siegrist, M. Trust and Risk Perception: A Critical Review of the Literature. *Risk Anal.* **2021**, *41* (3), 480−490.

https://doi.org/10.1021/acs.jchemed.4c00074
J. Chem. Educ. 2024, 101, 1635−1641