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Observing liquid crystals through a liquid crystal

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ABSTRACT

During the 23rd Andalusian Science Week at the University of Granada, we conducted an outreach activity titled *Observing liquid crystals through a liquid crystal*, aligning closely with our research project *Unveiling the boundaries of* biaxial nematics *for energy-efficient displays* UNBOUND. This initiative, targeting high school students, aimed to disseminate knowledge about liquid crystals and their practical applications, providing a realistic glimpse into scientific research. The activity consisted of an educational presentation and interactive experiments, with the latter proving particularly effective in engaging the students. This highlights the significance of interactive and engaging methods in effectively communicating scientific concepts to an audience of no-experts. Overall, the activity received positive feedback, and we plan to continue refining and implementing this format in upcoming public outreach events.

KEYWORDS

Liquid crystals; outreach; public engagement; high school education; research

Background and context

The 23rd Andalusian Science Week, known in Spanish as *Semana de la Ciencia en* Andalucía, unfolded from November 6 to 19, 2023. This annual event gathers a broad spectrum of knowledge-based entities from across Andalusia, Spain. In this edition, participation extended to 9 public universities, over 40 scientific institutions, and more than 100 educational entities, ranging from schools and associations to companies [1]. Organised by the Department of Universities, Research, and Innovation of the Andalusian Regional Government (in Spanish, *Consejería de Universidad, Investigación e Innovación de la Junta de Andalucía)* and coordinated by the *Fundación Descubre,* a non profit organisation dedicated to promoting scientific research and knowledge dissemination [2], this festival serves as a platform to showcase significant advances in science and research within the region. The event features a diverse range of activities, such as seminars, conferences, educational trails, guided tours, open days, and interactive workshops, with the overarching goal of delivering quality, sustainable, and inclusive science to the people of Andalusia. It underscores the crucial role of investing in both applied and fundamental research.

The University of Granada has a rich history of active participation in Science Weeks. The current edition aligns with the objectives outlined in the VII Plan for Science and Innovation Dissemination, a strategic initiative led by the University's Scientific Culture Unit [3]. A diverse array of over 150 outreach activities was meticulously curated, covering a wide spectrum of knowledge domains. These activities were thoughtfully organised into 166 itineraries, each tailored for groups comprising 20 to 30 students from primary and secondary schools. Participation in these itineraries was coordinated through formal requests from schools. The activities unfolded across various centres within the University of Granada, with the Faculty of Sciences alone hosting an impressive lineup of over 140 engaging events grouped in 40 different theme-related activities.

In this context, our commitment to science dissemination led us to propose an outreach activity designed to share our ongoing scientific endeavours with the wider public. In collaboration with Dr. Dierking and Dr. Avendaño, members of the Department of Physics and the Department of Chemical Engineering at the University of Manchester, respectively, our research group is actively engaged in the project *Unveiling the boundaries* of *biaxial nematics for energy-efficient displays* (UNBOUND). The primary objective of this project is to comprehend the conditions for the formation of biaxial nematic liquid crystals and to characterise the dynamics of uniaxial-to-biaxial switching. This holds tremendous potential for applications in developing more efficient and sustainable electronic displays. Leveraging our specific expertise in molecular modelling and simulations,

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Figure 1. From left to right: Irene Adroher-Benítez, Adrián Díaz Acosta, and Alessandro Patti ready to start their session on liquid crystals.

our outreach activity, titled *Observing liquid crystals through a liquid crystal*, places a spotlight on the role of computer simulation in liquid crystal research. In Figure 1, we stand ready to commence the first session of the activity, which took place on 8 November 2023, at the Faculty of Sciences of the University of Granada.

Motivation

There are several compelling reasons for researchers to engage in public outreach scientific programs. While motivations for such involvement can be personal, they often derive from a sense of societal responsibility [4]. In our specific case, multiple factors inspired our participation in the Andalusian Science Week through the proposed outreach activity. Primarily, as UNBOUND is funded by the Government of Andalusia, we feel obligated to transparently demonstrate how regional funds are utilised. Simultaneously, it is our duty to bring science closer to young adults, making an effort to kindle their interest in science and provide clarity regarding the role of scientists in society [5]. Furthermore, the funding body of UNBOUND expects a portion of our time to be dedicated to disseminating our findings to both the scientific community and the general public. Lastly, our engagement aligns with Horizon Europe's emphasis on science communication and public engagement, integral components of contemporary research funding frameworks [6]. This participation also contributes to the 2030 Agenda for Sustainable Development by enhancing public awareness and fostering informed societal actions [7].

From a professional standpoint, engagement in outreach events yields several advantages. These occasions foster interactions with colleagues from diverse fields, creating opportunities to broaden our professional network and establish foundations for future collaborations. Participation from researchers at other institutions involved in our project promotes a dynamic exchange of experiences, enhancing the collaborative environment of the project [8]. Moreover, the conceptualisation and preparation of an outreach activity represent an intellectual task in their own right, demanding a robust understanding of one's field and the capacity to articulate complex topics to an inexperienced audience with a balance of rigour and simplicity.

Audience profile

The outreach activity detailed here was organised into three separate sessions, each catering to high school students from the Granada province. IES Sayena in Castell de Ferro and IES Acci in Guadix are integral parts of the Spanish public educational system, while Agora Granada College International School in Atarfe operates as a private institution. The session for IES Sayena involved 17 students in their third or fourth year of compulsory secondary education (ages 14–16), while the sessions for IES Acci and Agora Granada College were dedicated to 20 first-year students in non-compulsory secondary education (ages 16–17). These sessions were integrated into a unique day organised by their respective schools, specifically designed for participation in the Science Week activities hosted by the Faculty of Sciences at the University of Granada. Alongside our workshop, each student group engaged in two additional scientific outreach sessions on the same morning, facilitated by other collaborating researchers.

Materials

To perform our experiments, we acquired 5 g of 4-Cyano-4′-pentyl biphenyl (CAS 40817-06-1, supplied

by CymitQuímica, S.L.), a nematic liquid crystal commonly referred to as 5CB and consisting of rod-like molecules. At $T_{NI} = 35°C$, these molecules lose their orientational order and 5CB transforms into an isotropic fluid.

For the initial experiment, we utilised a small test tube to house the liquid crystal, which could be conveniently inserted into larger test tubes filled with either hot (above T_{NI}) or cold (below T_{NI}) water. To heat water, we employed a conventional kettle. A red laser pointer was then used to demonstrate the scattering of light through the nematic liquid crystal. The second experiment required two microscope slides, linear polarising sheets, and a standard hairdryer for heating the liquid-crystal sample.

Description of the activity

The activity, *Observing liquid Crystals through a liquid Crystal*, spanned approximately 45 minutes and included a slide presentation intertwined with two *in situ* experiments. The presentation commenced with an introduction to our team. One of the three speakers shared our names, delineated our roles at the University of Granada, and introduced our research group and department. Subsequently, another speaker seamlessly carried forward with the presentation.

While we anticipated that the students might be familiar with liquid crystals, we initiated the presentation by providing an explanation of their nature. With the aid of appropriate figures, we simply presented liquid crystals as an intermediate state of matter, positioned between liquids and crystals.

Subsequently, we focused on their practical applications and, recognising the captivating appeal of electronic devices, especially among teenagers, we specifically described how liquid-crystal displays (LCDs) work. To this end, we dedicated a slide to elucidate the concept of light polarisation. At this juncture, as one speaker elucidated the fundamentals of this phenomenon, the other two researchers distributed pairs of linear polarising filters to the audience. This allowed each student to observe firsthand how light is blocked when two sheets are oriented at a 90-degree angle. Following the explanation of light polarisation, we proceeded to illustrate the workings of a single pixel in a generic liquid-crystal display, using a graphical scheme displayed on a slide.

Having elucidated the fundamentals of liquid crystals and their applications, we transitioned to detailing our research work at the University of Granada. We considered this segment particularly crucial, as one of the primary objectives of this activity was not only to convey basic physics concepts but also to showcase the practicality of engaging in research. Mindful of our relatively inexperienced audience, we maintained a straightforward explanation, outlining our primary focus as the discovery of molecules capable of forming a biaxial nematic phase. The integration of such molecules into electronic displays holds the potential to enhance performance by reducing the response time and energy costs associated with transitioning between biaxial and uniaxial nematic phases. We underscored the computational and theoretical nature of our work, distinct from the traditional image of scientists in lab coats engaged in experimental laboratory work [9]. Our explanation was complemented by a video derived from our computer simulations, providing a visual representation of the formation of a nematic phase in large board-shaped molecules.

We then paused the presentation to conduct two experiments. The first aimed to illustrate how temperature influences the nematic-to-isotropic phase transition in the 5CB liquid-crystal sample under consideration. To this end, we placed the liquid crystal inside a test tube and utilised two larger test tubes, one filled halfway with hot water and the other with cold water. Circulating among the students, we demonstrated how the sample appeared milky at low and room temperatures, becoming transparent when immersed in hot water. To actively involve the students, we selected two volunteers to hold the cold and warm test tubes, directly participating in demonstrating the experiment to their peers. Additionally, a laser pointer was employed to visually depict how light scattered in the nematic phase and passed through almost unaltered in the isotropic state, as illustrated in Figure 2.

The second experiment entailed the creation of a 'home-made pixel', as illustrated in Figure 3. We applied a drop of 5CB liquid crystal between two microscope slides to form a uniform film. Pairing up the students, each held a sheet of polarising filter, with one rotated by 90 degrees relative to the other. Initally, they could not see each other through the filters due to the linear polarisation of light. However, upon introducing the microscope slides containing the nematic liquid crystal, they could see each other again, as the liquid crystal altered the light's direction. We repeated the experiment after heating the sample with a hairdryer, demonstrating that isotropic fluids cannot influence the light's direction as nematic fluids do, making the students unable to see each other through the filters.

After involving the entire audience in these hands-on experiences, we concluded the presentation by acknowledging the public agencies that funded our projects, emphasising the crucial role of such support in fostering scientific research. Subsequently, we welcomed questions from the audience, encouraging

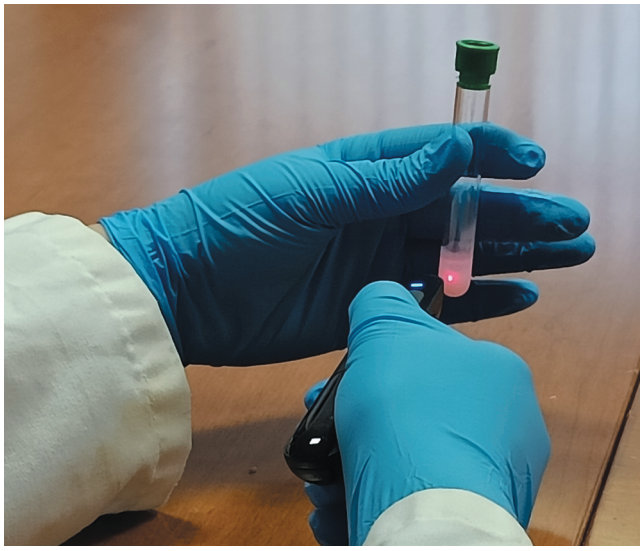

Figure 2. Photograph depicting the first experiment, illustrating the dispersion of light from a red laser as it traverses a sample of 5CB liquid crystal in its nematic phase.

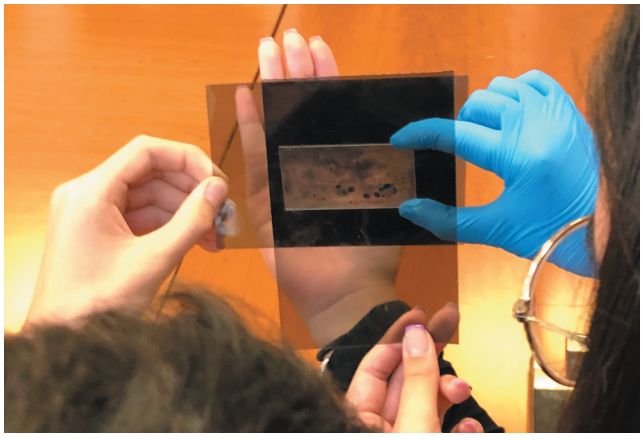

Figure 3. Photograph depicting the "home-made pixel" experiment, featuring a nematic-phase 5CB liquid crystal sample positioned between two polarising filters oriented at 90 degrees to each other.

students to inquire about any aspect of the presentation or share their curiosities. This sparked a vibrant exchange where we addressed several of their intriguing questions.

Observations and feedback

Throughout the session, the students exhibited excellent behaviour, actively participating without the need for teacher intervention. While varying degrees of interest were noticeable, all students listened respectfully during our presentation. Their surprise upon discovering that our work primarily involves computational techniques rather than traditional laboratory experiments was notable. The video showcasing actual simulation results particularly captured their attention. Moreover, a significant number of students across sessions expressed curiosity about the applications of liquid crystals in electronic devices, posing several questions about the underlying technology.

The most engaging aspect of the activity was undoubtedly its experimental part. Initially, the students not only showed interest in experimenting with the linear polarising filters, but also demonstrated considerable enthusiasm. Later, inviting volunteers to assist in the first experiment proved effective in maintaining the attention of their peers, with active participants visibly enjoying the experience. The 'home-made pixel' experiment also generated significant interest, fostering interaction among classmates as they collaborated in pairs.

At the end of the session, we had the opportunity to discuss with some of the teachers, and they expressed satisfaction with the experience. Overall, we believe the students not only enjoyed the session but also gained a basic understanding of liquid crystals and a new perspective on a facet of scientific research.

Conclusions

In summary, we have outlined the outreach activity *Observing liquid crystals through a liquid crystal*, conducted during the 23rd Andalusian Science Week at the University of Granada. This activity, aligned with our research project *Unveiling theboundaries of biaxial nematics for energy-efficient displays* (UNBOUND), was presented three times in various sessions to high school students from the Granada province, in Spain. Our primary objective was to share our current research work with the students, not only to inform them about liquid crystals and their applications, but also to provide insight into the diverse profiles of scientists in academia, offering a more realistic vision of our proffesion and duties.

The activity comprised two main parts: first, a slide presentation introducing liquid crystals, and second, two experiments designed to engage the audience and reinforce their newly acquired knowledge. While the presentation was educational, the experiments appeared to capture the students' interest more effectively. We interpret this not as a deficiency but as an essential aspect of outreach, where the primary aim is to spark interest in science rather than merely transfer fundamental knowledge. In this regard, we believe we achieved our goal.

We are considering further enhancements to this activity in the future. While the content of the talk was suitable, increasing the level of interactivity could be beneficial, given the positive audience response to the

experiments. For Instance, when discussing the applications of liquid crystals in electronic devices, we could bring a partially disassembled device to the session, allowing students to see its construction. Another idea is to develop an interactive video from our simulation results, granting students some control over variables like temperature or pressure. This could include features allowing them to observe phase transitions and examine molecule orientations. Implementing these improvements would necessitate additional computational work on our part, but they could significantly enhance the students' understanding of the research conducted by our group.

In conclusion, we are extremely pleased with the success of this initiative and intend to replicate and refine it in future editions of the Andalusian Science Week and other public engagement events.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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