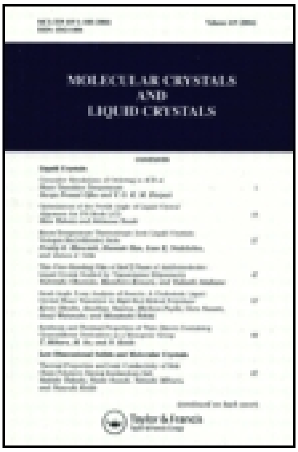

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How to Teach Liquid Crystals?

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How to Teach Liquid Crystals?

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We present a teaching unit on liquid crystals. The unit has already been implemented into the university undergraduate pedagogical study programs for future teachers of Physics and Chemistry, preschool teachers and teachers at the lower grade of the elementary school at Faculty of Education, University of Ljubljana. The unit develops students' knowledge on the existence of more than three phases of matter and the existence and properties of anisotropic materials, focusing on the biaxiality and birefringence. The unit is multidisciplinary since students perform the experiments with the MBBA nematic liquid crystal which they synthesize themselves. Our final goal is to implement the teaching unit to the high school curriculum (for students 14–18 years old).

Keywords Double refraction; experiment; liquid crystal; phase transition; synthesis

1 Introduction

How can we motivate students in learning science? Current school science (Chemistry and Physics) in many European countries has little in common with students' experience, even when technological applications are introduced [1]. This leads to a lack of relevance to study science, and provides students with little motive to learn scientific concepts [2]. Students very often experience a gap between the abstract and difficult chemical and physical concepts they learn at school and the world they live in [3].

Science teachers, researchers and politicians alike have reasons for motivating students to study science. This desired motivation, however, involves sustained effort and not just temporary excitement. Getting students interested in or enthusiastic about science is a good start, but motivation to learn requires a supported commitment to develop scientific knowledge and make use of it in the everyday life [4].

A possible way to achieve this is by context-based approaches which aim to bring the students' learning closer to their own experiences. There are several context based

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approaches [5], but they all have a common characteristic: they provide the student with the need to learn. This means that activities are planned in such a way that students experience learning of chemical and physical concepts as relevant for them [6].

Liquid crystals are a perfect topic (context) which enables the development of different chemical and physical concepts. Liquid crystals are omnipresent substances, which also exist in natural systems. They are used in displays, phones, laptops,... students live and grow with modern technology, using modern equipment, which is technically very complex. Students often do not understand how modern equipment works, even if they are interested in it [7].

Since we encounter liquid crystals in everyday devices on every step of our life they are a source of interdisciplinary contents, strongly connected to daily life of students. Nevertheless the results of the liquid crystal questionnaire performed among the first year undergraduate students shows that students are aware of liquid crystals but nothing more [8, 9]. Since liquid crystals are not included as a topic in the pre-university school curriculum in Slovenia this shows that the informally obtained knowledge of liquid crystals is practically nonexistent. The questionnaire has also checked the knowledge on the existence of more than three phases and the existence and properties of the optically anisotropic materials. Although only minute knowledge was expected, it came as a surprise that also in this case the knowledge is practically nonexistent. This served as a motivation to prepare a teaching unit on liquid crystals, combining their chemical and physical properties. The main aims of the unit are to teach students what liquid crystals are, to introduce an additional phase and to show special optical properties on which liquid crystal display (LCD) technology is built.

The teaching unit is presented in this paper. Our final goal is to test and implement this unit in the secondary schools for pupils of the age between 14–18 years. However, we have begun by implementing it at the university level within the study programs for future teachers of Physics and Chemistry and we have also successfully implemented it into the study program for students who are studying to become teachers for 6–9 year old children as well as preschool teachers. The unit can also be used in the activities promoting natural sciences.

2. Teaching Unit on Liquid Crystals

While designing the unit we had in mind the following goals:

–to design an interdisciplinary teaching unit (school knowledge is highly fragmented and because of that it is difficult for students to connect the content from difficult subjects into a meaningful entity) [2,10],
–to increase the interest in science (young people, in general, are not interested in science) [9,11],
–to connect the school science and students' experiences (it is too often that school science has nothing in common with students' experiences),
–to make a teaching unit with several experiments (in science classes there is a lack of experiments even though students, in general, like experimenting) [12],
–to design the teaching unit with the science content necessary for the basic understanding of the problem set by the context [13].

The teaching unit is composed of a lecture in duration of 90 minutes and a practical laboratory work in chemistry and physics of the same duration. The activities within the teaching unit are designed in way that leads students to the appropriate explanation of how liquid crystal displays work. The lecture gives basic properties of the liquid crystals as materials having a peculiar phase between the commonly known isotropic liquid and the crystalline state. Then the lecture introduces the optical properties of liquid crystals and the technology of LC displays. During the chemistry laboratory work students synthesize liquid crystal MBBA in the school laboratory [14].

The purity of the synthesized liquid crystal, which has a liquid crystalline phase at room temperature, is tested in the physics lab by measuring the phase transition temperatures by heating the cooled sealed test tube with the MBBA in a beaker with water. Then the synthesized liquid crystal is used to fill the cell which is made from the microscope slide, cover glass and a plastic foil. Liquid crystal is observed under the "polarizing" microscope: students use a usual school transmitting microscope and polarizing foils. They observe textures and colours in the LC cell they have produced. Students also heat the cell with a hair dryer and observe changes of colour and its disappearance as the liquid crystalline phase transforms to the liquid phase. Then students fabricate also a wedge cell [15] and use it to obtain divergent ordinary and extraordinary beams which are observed on the remote screen. Students verify that the two beams are polarized, polarization in one beam being perpendicular to the polarization in the other beam.

Below we give the instructions given to students and descriptions of the experiments included in the teaching unit.

Synthesis of the Liquid Crystal MBBA

Liquid crystal MBBA 4-butyl-N-((4-methoxyphenyl)methylene) belongs to a group of nematic liquid crystals, which are the simplest liquid crystals and most useful for the teaching purposes. MBBA is very interesting because it has a transition to a liquid crystalline phase at room temperature. Its synthesis takes only 90 minutes and it must be performed in a fume hood. The standard safety precautions must be followed and the use of the laboratory coat, safety glasses and gloves is necessary. Students have to read carefully the safety instructions for handling each chemical.

Students use the following procedure to synthesise MBBA [14,16]:

1. 1.48 g of 4-butylaniline and 1.37 g of p-anisaldehyde is put in the Erlenmeyer flask.
2. The Erlenmeyer flask is put on a stand with a glass plate. The mixture is carefully heated for 20 minutes. When the mixture is heated the amount of bubbles coming out of the solution should be minimized. The reaction ends when the cooled mixture becomes cloudy. The test is performed like this: the drop of liquid from the flask is poured on a watch glass and the mixture should become cloudy after a few seconds.
3. When the mixture of the product and reactant is cooled, it is poured into a separating funnel with 10 ml of toluene in order to remove the impurities.
4. Separating funnel is placed on a stand and 5% of aqueous solution of acetic acid is poured into it. The mixture is shaken in the separating funnel. The impurities and acid are collected in the lower layer of the separating funnel (aqueous phase).
5. The mixture is rinsed by a 5% aqueous solution of sodium hydrogencarbonate and then by the distilled water. The rinsing should be repeated several times.
6. The refined product is poured into a clean Erlenmeyer flask which is placed on a glass plate and heated in a fume hood until all the toluene evaporates. A product of an orange-brown colour is obtained. After the synthesis is completed, the liquid crystal MBBA is cooled and poured into the bottle and stored in the refrigerator.

Liquid Crystalline State

A cooled sealed test tube with the MBBA liquid crystal is put in a beaker with cold water. Students heat the water, record the change in temperature and observe what happens with the liquid crystal in a sealed test tube (Fig. 1). They are asked to describe what is happening with the liquid crystal when its temperature increases. They record the temperatures when the substance in the test tube begins to flow and when it becomes clear. Both temperatures indicate the phase transition temperatures. The first temperature indicates the phase transition from the solid phase to the liquid crystalline phase and the second from the liquid crystalline phase to the isotropic liquid phase.

Prototype LC Cell with Non-Ordered Liquid Crystal Molecules

A planar liquid crystalline cell with non-ordered liquid crystal molecules is made. Students take a microscope glass and wrap around it two strips of foil usually used for food wrapping food as shown in Figure 2. A drop of liquid crystal is put on a microscope glass between the two strips and a cover glass is carefully put over. Then the students observe their cell under the microscope (magnification: 300) between two crossed polarizing foils and describe what they observe (Fig. 3). They also observe and record what happens when they rotate one polarizer and are asked to describe the changes in colours. Finally they heat the cell with a hairdryer and observe the transition to the isotropic liquid.

Prototype LC Cell with Ordered Liquid Crystal Molecules

A similar procedure is used to make a liquid crystalline cell with ordered liquid crystals molecules. This time the cover glass is rubbed along one side with the velvet soaked in alcohol. The cell is observed between two crossed polarizing foils under a microscope and students describe what they observe. What happens when they rub the cover glass with velvet? How are the molecules of liquid crystal aligned? Then they rotate the polarizing foil and describe their observation (Fig. 4).

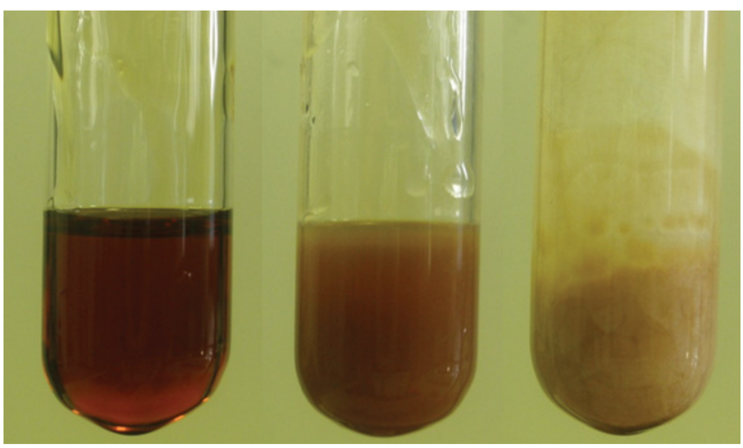

Figure 1. Liquid (left), liquid crystalline (middle) and solid (right) phase of MBBA. (Figure appears in color online.)

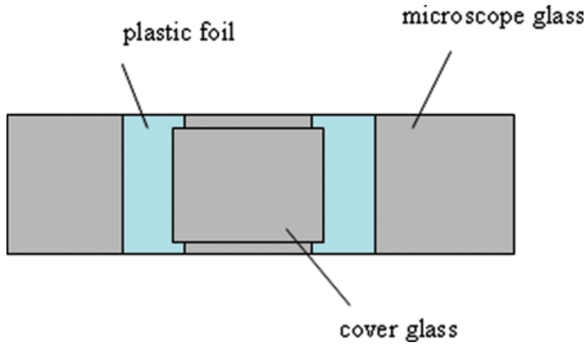

Figure 2. A sketch of a planar cell with parallel glass plates. (Figure appears in color online.)

Visualization of the Double Refraction (Birefringence)

Students make the wedge cell as shown in Figure 5. A laser light from a laser pointer is directed through the wedge cell filled with liquid crystal (Fig. 6). They search for the area of the cell where the laser light beam is split into two beams which are observed on a remote screen (Fig. 7a). A polarizing foil is used to check if the beams are polarized

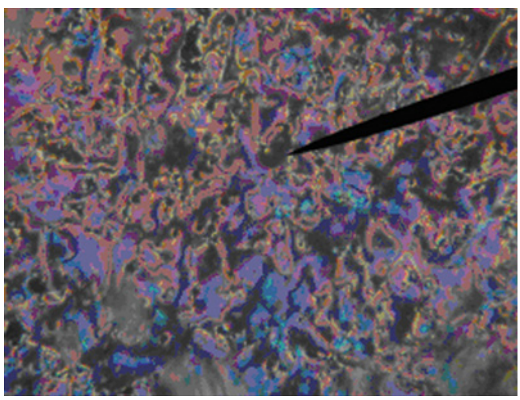

Figure 3. MBBA in a planar cell between crossed polarizing foils and observed under a microscope. The black line is a pointer of the microscope. (Figure appears in color online.)

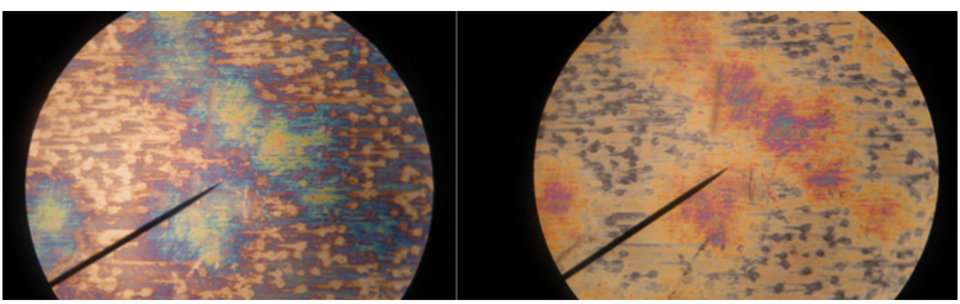

Figure 4. MBBA in a planar cell with notches, observed under a microscope when polarisers are crossed (left) and parallel (right). (Figure appears in color online.)

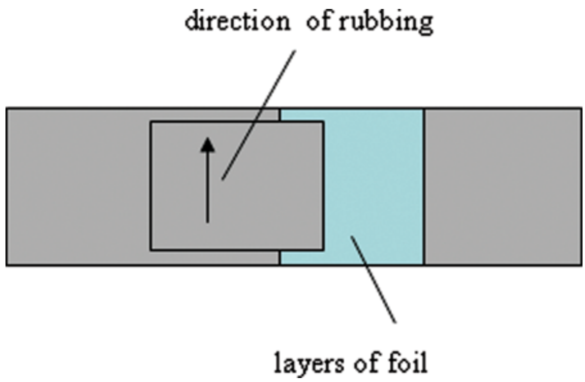

Figure 5. Wedge cell. (Figure appears in color online.)

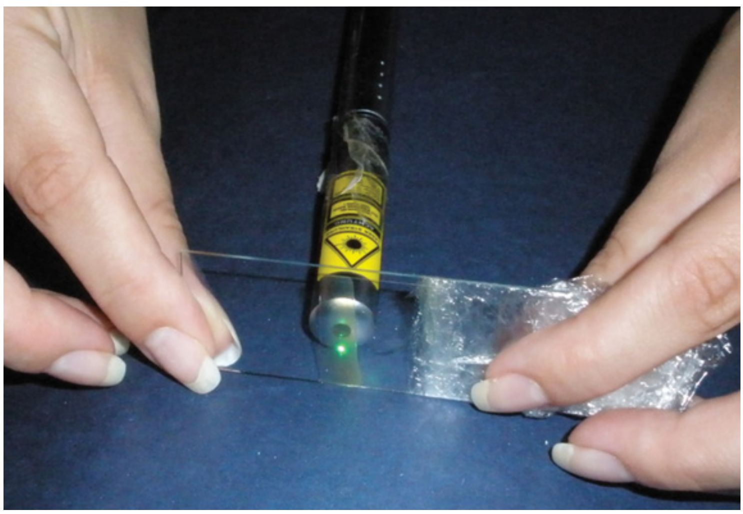

Figure 6. The experiment with a laser beam and a wedge cell. (Figure appears in color online.)

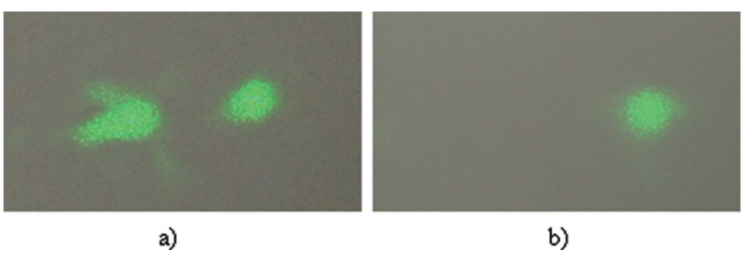

Figure 7. a) Double refraction in the LC phase, observed on the remote screen. Left: extraordinary beam; right: ordinary beam. b) After heating the liquid crystal to the isotropic phase only one beam is observed. (Figure appears in color online.)

and the direction of polarization of each beam is determined. Students are asked to sketch the experiment and polarization of light. Then they heat the cell with a hairdryer and observe and explain what happens with the light spots on the screen (Fig. 7b).

3. Conclusions and Perspectives

Europe faces the problem of low motivation for natural science studies. Introduction of contemporary research and technological problems into science teaching makes the context of learning more motivating especially when students are actively involved. Inclusion of topics on liquid crystals into syllabus makes studying of physics more meaningful as it brings everyday life into the classroom. In this paper we have presented a teaching unit on liquid crystals. The unit has already been implemented into the study courses for future teachers (pre-school, young children (6–9 years) and Physics and Chemistry teachers). The evaluation of the teaching unit is still in process. The aims of the unit are to teach students what liquid crystals are, to introduce an additional phase and to show special optical properties on which liquid crystal display (LCD) technology is built. Our final goal is to implement topics on liquid crystals into the secondary school curriculum of Physics and Chemistry as an example of the interdisciplinary approach to modern science teaching.

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