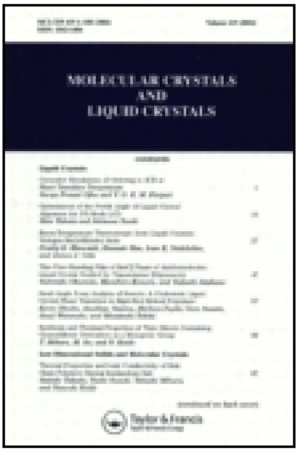

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Liquid Crystals and Development of Natural Science Competences

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Liquid Crystals and Development of Natural Science Competences

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Understanding physical phenomena in education often requires a good three-dimensional (3D) imagination. Visualization software mainly uses either active 3D virtual simulations or static two-dimensional cross-sections for presenting real physical systems. We performed a comparative study of students' comprehension of both visualization approaches in the field of fundamental liquid crystal (LC) phases. We also developed a mechanical teaching tool—three boxes with wooden rods attached on vertical strings, in order to simulate the transitions between LC phases. We found that both the software and mechanical visualizations are efficient for representation of LC phases as well as training natural science competences.

Keywords Didactics of physics; visualization of phases and phase transitions; mechanical teaching tool; natural science competences

1. Introduction

Understanding the physical phenomena in education often requires a good three-dimensional (3D) imagination of the system under study, in order to enhance the understanding of chaos and nonlinear dynamics, for example [1–5]. This is of great importance, for instance, when contemporary scientific discoveries are introduced within physics lessons in primary school [6]. Visualization software uses two main approaches for presenting 3D physical systems on two dimensional (2D) screens: active 3D virtual simulation (e.g. VRML files; VRML = Virtual Reality Modeling Language) or a set of static 2D cross-sections of the same structure from different directions [7–11]. The two approaches will be briefly denoted by 3D and 2D view, respectively.

The field of liquid crystals (LCs) has been present in scientific research for several decades. The research is intensive both in the field of LC applications and in basic LC science [12–15]. As early as in primary school students are familiar with the use of LC devices, particularly LC displays (LCDs) on mobile telephones and notebook computers; also the LC projectors are more and more frequently used in school practice. Students are curious and they search for the explanation about the mechanisms of these devices. Unfortunately, they often fail to get the answers to their questions, although it would be

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reasonable to expect that at least the school education should provide the right answers. Teachers are probably the students' first target when looking for help. It has been found that Slovene teachers commonly have too modest knowledge about LCs to feel competent for giving correct answers [16]. Very little suitable didactic literature is available for this field, and the situation with appropriate didactic tools is even worse. Learning contents on LCs are not explicitly cited in the formal Slovene primary school curriculum (students' age between 6 and 15). On the other side, it is stated that within the approximate amount of 70 hours of physics per year (last two years) about 20 hours are not defined in learning content; they can be used for introducing contemporary scientific discoveries and practical applications, among other possibilities. Therefore, the teacher has a formal chance of treating LC topics within primary school physics.

LC contents are, in didactic sense, appropriate for the primary school level [14], because they enable teaching with various methods [6]. It is of particular importance that studying LCs can be accompanied by a plenty of appropriate experiments [17–19].

It is this variety of didactic methods, together with actuality and inter-disciplinarity of LCs, that makes their study important from another point of view: natural science competences [13, 20]. Comprehension of complex structures and phenomena (LC structures, phases and phase transitions) demands a very good ability of visual imagination. In this paper we described how appropriate visual imagination of 3D structures in the field of LCs can be trained at different educational levels. We will also show how a suitable didactic approach can be chosen in order to introduce contemporary scientific achievements and applications in primary school physics.

2. Didactic Research of the Role of Liquid Crystals in Education

The majority of media where 3D LC structures are shown are 2D. Some examples of this are: 2D sketch, cross-sections from different views, graphic results of computer simulations, etc. Different solutions are used to ease the imagination of the 3D structure on 2D medium: shading, differences in scaling objects of the same size but at different distances, colours, simultaneous presentation of two or more different cross-sections of the same structure, etc. Among the most successful tools is the use of VRML files (when appropriate managing computer programme is also available) since it enables the study of the structure in different directions with several virtual space operations: rotations, shifts, zooming and penetration.

VRML files were developed for high-school students, where the ICT (Information Communication Technology) is used to study the basis of LC phases and structures (different point and line defects, biaxiallity, domain pattern, twist, bend and splay deformations, etc.; see Fig. 1) [13, 21].

We performed a comparative study of comprehension of both views (static 2D and dynamic 3D) for two groups of high-school students (educational physics): those familiar with LCs and those who had not heard of LCs yet. We found that students with experiences in this LCs prefer the use of the 2D view while other students are significantly worse in interpreting the 2D views [14,16].

Before the LC topics are introduced in the physics lessons in primary school, it is advisable to think about didactic methods, to talk with teachers about this point, so that appropriate topics, experiments and methods are finally chosen. For this reason, in addition to the didactic research with students mentioned above, [13] two researches have been done for the primary school level [6, 14]. They are both described in continuation.

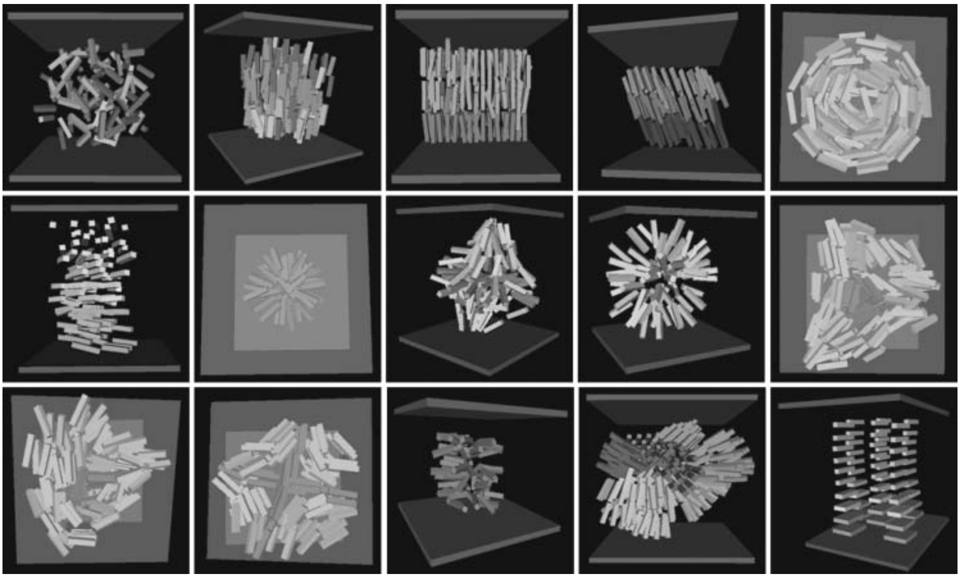

Figure 1. VRML files showing LC phases, deformations, point and line defects, domain pattern and biaxiallity.

2.1 Comparison of Three Different Didactic Approaches when Introducing LC Topics in Primary School

In the first, more extensive research we studied which didactic approach (a combination of form and method of teaching) is the most efficient when we want to introduce contemporary scientific achievements in the frame of content-undefined physics lessons in primary school. We tested three approaches: 1) frontal explanation with discussion, 2) work with text, and 3) the use of ICT. Twelve different physics topics were used, and LCs was one of them. Pre-test and post-test (each including 7 questions with growing cognitive level of knowledge, demanding higher and higher assessment/reasoning strategies: memorizing, analysis, comparison, inference and interpretation, and evaluation) were used to measure the students' knowledge acquisition in the school lesson. We found that students are much less successful in solving tests when the cognitive level increases, irrespective of the didactic approach used [13,20–23]. Some correlations between the success in solving tests and predispositions of students were also verified. For instance, students with better marks in the school subject with physics contents in the past year were more successful in test questions requiring higher cognitive level of knowledge. It was also shown that the students' gender and stratum (city schools vs. country schools) have no statistically relevant influence on success in tests. An interesting finding was that the success was not significantly different in the case of 8th and 9th year of primary school (when the independent subject physics is taught). Thus, any of these interesting actual scientific topics can be introduced either in the 8th or in the 9th year.

2.2 Mechanical Teaching Tool for LC Phases

We have seen or heard many suggestions for the construction of a mechanical device to simulate LC phases and structures. Some very interesting models presenting the LCs properties by wood [18] and the phase transitions in LCs by springs [19] have already been put forward. Since we are aware of the meaning of good 3D imagination of complex structures, we seek for new ways of illuminative presentations of these structures all the time. We appreciate the significance of the construction of mechanical model for LC structures for educational purpose. In the frame of the national project Development of Natural Science Competences [20], we designed and fabricated the model—three transparent boxes with wooden rods attached on vertical strings, in order to simulate the LC phases: isotropic (I), nematic (N), smectic A (SmA), smectic C (SmC), and three transitions between them: I-N, N-SmA, and SmA-SmC. We achieved this by suitable arrangements where stretching the strings can change the positions and/or orientations of the rods. We limited our presentation to LCs with rod-like molecules and head-to-tail invariance of nematic director. The first box is aimed to represent both isotropic and nematic phases, as well as the transition between them. The second box enables the view of nematic and smecticA phases with the corresponding phase transition; similarly, the third box represents the transition between the two smectic phases (Fig. 2).

The boxes are shaped as cubes with the edge of 0.5 m; they are made of Plexiglas. Their size is sufficient for frontal experiments in class, where the teacher can demonstrate the usefulness of this mechanical tool and lead the frontal discussion about the LC phases. Simulation of phase transition is performed by turning two handles on both sides of the box. But in the first place, this mechanical learning tool is intended for individual work of students. When students get the opportunity to play with the boxes, they can observe the change of orientational and/or positional order of the wooden rods representing either individual LC molecules or groups of them (Fig. 3).

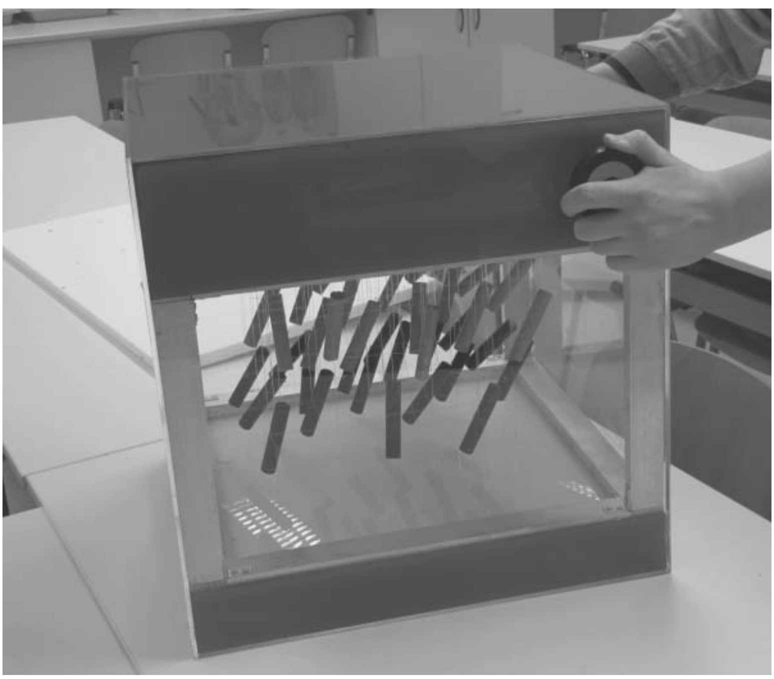

Figure 2. Mechanical teaching tool for presentation of smectic A to smectic C phase transition due to rotation of double handle.

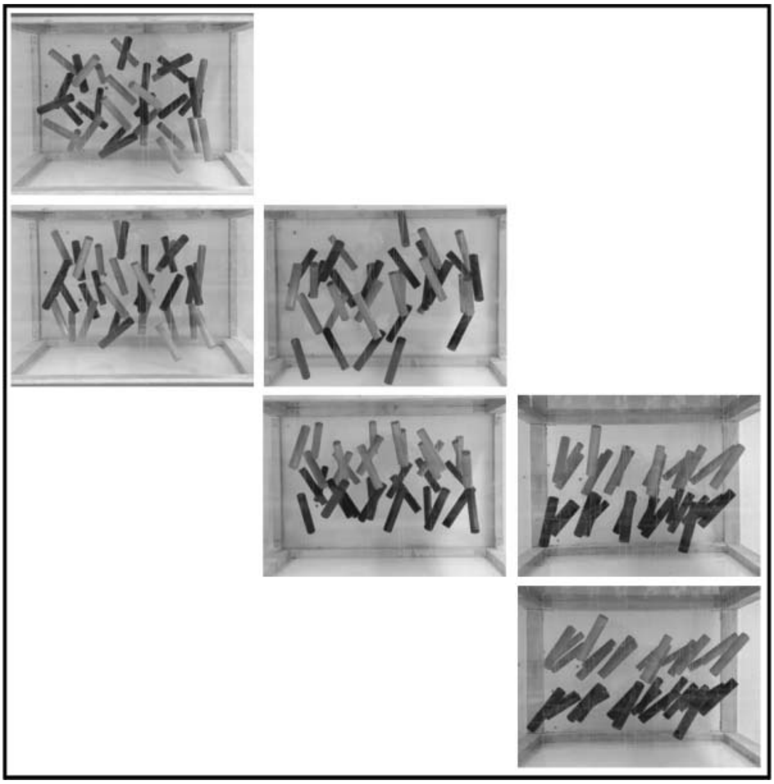

Figure 3. Different LC structures are presented with three boxes (in three columns). Four LC phases (I, N, SmA, SmC) are shown in the four rows. Three phase transitions (I-N, N-SmA, SmA-SmC) are presented from row to row.

3. Liquid Crystals in Schools and Development of Natural Science Competences

The development and use of the mechanical learning tool for the presentation of LC phases and transitions between them in primary school was done in the frame of the project Development of Natural Science Competences, as already mentioned [20]. We found that these boxes are a very convenient learning tool, not just for better understanding of LC phases, but also for developing students' generic competences connected with information management [24,25]. The didactic research with the use of this learning tool was performed in the 8th and 9th year of primary school, where 404 students from five schools were involved. The progression in the students' competences through the use of the mechanical tool was observed qualitatively. The following competences/activities were investigated: 1) collecting information, 2) their analysis, 3) synthesis of conclusions, and 4) interpretation. The successfulness of the learning tool in acquiring students' competences can be attributed to the fact that the essence of the three boxes is similar enough while the corresponding phase transitions are qualitatively different anyway. In this way, the level of the acquired particular competence with the use of the first box may be upgraded when playing with the second box. In the case of the third box (SmA-SmC transition) the level of acquiring the competences was estimated (determine percentage of successful students at gaining

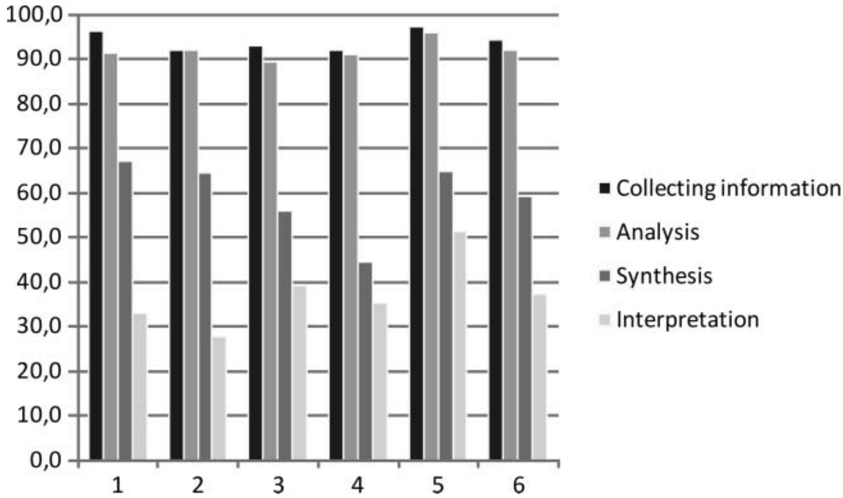

Figure 4. Opinions of five cooperating teachers about the development of the four competences through the use of the mechanical didactic tool for LC phases and transitions between them. The first 5 column groups are assigned to individual schools while the sixth group of 4 columns indicates the overall average success for all schools. The left axis denotes the percentage of successful students at gaining observed competences.

observed competences, separately for each school and in average). The conclusion was the following: within a single school lesson of physics the students showed the progress in the competences of collecting and analyzing information, but the satisfactory progress in regard to synthesis of conclusions and interpretation was significantly smaller (Fig. 4).

The goal of developing natural science competences is not the same as merely acquiring basic facts about the world around us; it is also oriented to other components of general and specific competences for lifelong learning: skills and abilities, as well as personality attributes (character, behaviour, convictions, etc.). They can be trained only by appropriate didactic methods which force students' activity; the mere choice of the appropriate science topic is not enough. Teachers have to possess required competences in order to guide students in right direction (for instance, the generic competence ability of collecting information from the Australian list of competences [24]). Let us illuminate this point: when the student (or teacher) searches specific information with physics contents on web pages, he or she must be aware of the possibilities of mistakes and misinterpretations in the explanations, numbers, equations, etc. Any new important information should be verified, for instance, by comparison with other sources, or possibly, by the user's own estimations and calculations. This requires the sense of responsibility and care for quality, not just specific skills.

4. Summary

The use of software and mechanical didactic tools (in our case, for instance VRML files and the three boxes for presentation of LC basic phases) has two main goals: 1) effective three-dimensional visualization of complex physical systems which enables the proper student's understanding of them, and 2) developing and training various natural science competences. We conclude that this approach can be successfully performed at all levels of formal educations: from primary to high schools. Here, we focused on some generic competences connected with scientific observation of natural phenomena.

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