HANDICRAFT AND AESTHETIC EXPERIENCE IN TEACHING CHAOS PHYSICS

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ABSTRACT

Our aim is to raise awareness of the importance of getting acquainted with chaos physics in the frame of teaching modern physics. We would like to present a good practice of a series of lessons with a focus on handicraft activities. Apart from raising interest, experiencing the joy of creating something, the activities may help students understand and deepen their knowledge of chaos physics.

INTRODUCTION

We examined the opportunities of getting acquainted with chaos physics within the framework of secondary school physics education, as I presented in a Hungarian language article [1]. We researched the methodology of inserting chaos physics within the secondary school curriculum, presented chaos experiments, introduced IT opportunities and also reviewed the use of art as a 'motivational tool'.

In this article we present how art workshops inserted in a series of chaos physics lessons are capable of raising interest in physics and the chaotic phenomena within thereof, and shall provide opportunity to explore the features of chaos. Our aim is to raise awareness of the importance of getting students acquainted with chaos physics within the framework of modern physics education, we shall provide ideas thereto and present some good practices.

We encounter chaotic phenomena not only in our everyday life [2], but also in nature: at the change of ocean plankton colonies in space and time (see e.g. [3]); or fluid layers mixing in turbulent sea, or in meteorology [4] the spread of clouds of pollutants. We can also take the shooting stars across the sky at summer nights as examples, which trace out the final phase of the chaotic motion of small asteroids. Another example can be the oscillation of the heart and brain activity, or the oscillating chemical reactions.

As we notice, chaotic motion is not exceptional but typical. It is the complex behaviour of simple systems [5]. The main characteristics of deterministic chaos are: the equations describing the motion are known; these equations are nonlinear; the motion is irregular and unpredictable; there is order in the phase space: the fractal [6] structure. As these phenomena are so typical for physics and everyday life, chaos physics should belong to the physics curriculum.

THE PLACE OF CHAOS PHYSICS IN SECONDARY SCHOOL PHYSICS EDUCATION

In a former research we investigated how the possibility of teaching chaos physics may be implemented in secondary school physics education [1]. We examined two education systems: a Romanian model and a German model. Teaching the elements of chaos physics is

part of Modern Physics in the examined Romanian model, whereas similar elements are integrated in the relevant chapters in the other model.

Chaos physics can be defined as modern physics in a non-conventional sense. Currently, chaos physics is not part of the official documents of the Hungarian secondary education. In a series of lessons, we examined the possibility of implementating chaos physics and our recommendation was given in a syllabus prepared on the basis of the national curriculum (NAT): we concluded that it should be connected to topics related to environmental physics. We may encounter several environment-related topics within the syllabus, which is rich in terms of different phenomena; however, the depth of understanding is rather low. We think that chaos physics should have an important role in the preparation and academic founding of these topics.

I have developed a teaching unit that I have implemented in different classrooms. This unit includes complementary contents to the already existing curriculum. As a first step the teacher familiarizes students with chaos theory and its characteristics throughout simple mechanical examples (e.g. magnetic pendulum, double pendulum, double slope [6]): the unpredictability, the order appearing in phase space, the fractal structures. As a second step, students are familiarized with mathematical fractals. As a next step the teacher demonstrates that fractal structures become visible during chaotic mixing. Students can observe fractal patterns during mixing (mixing cream in coffee, syrup in water, ink in water, or during mixing different paints). The main hands-on activity of this teaching unit is marbling. During handicraft activities students experience the process how patterns develop. After the hands-on activities we return to the topic of environmental flows. Students will be able to recognize similar patterns when encountering environmental contamination.

The method of inquiry-based learning is applied. Inquiry-based learning includes problem-based learning. Most of the PBL-defining characteristics listed by Schmidt [7] appear during the teaching process I implemented: problems are used as an activator for learning; students co-operate in groups for part of the time; learning takes place under the supervision and guidance of the tutor; this curriculum of chaos physics consists of a limited number of lessons. In certain situations learning is student-initiated, and we often provide time for self-study.

It is important to know what competencies the students develop while getting acquainted with chaos physics. Cooperation among the students is improved with team work. The group activity provides a good platform for collaboration and the development of friendships among students in addition it facilitates making closer contacts between the students and the tutor [7]. The interdisciplinary concept of the students is largely strengthened during these lessons. On the one hand, the aesthetic experience is suitable to raise interest and to motivate, whereas the classroom activity itself develops visual and aesthetic viewpoint. The students have the opportunity to observe, compare and interpret the phenomenon. Their competency of thinking in pictures is developed; they will be able to recognise similar patterns in different situations. It is very important to note that these are not fictional and virtual pictures, but pictures occurring in nature.

WHY SHOULD WE USE HANDICRAFT TO FAMILIARIZE STUDENTS WITH CHAOS PHYSICS?

In the above-mentioned series of lessons handicraft activities play an important role. The reason for this is the peculiarity of chaotic mixing. Fractal structures always appear in chaotic processes, but regularly in an abstract space, in the phase space [5], therefore they do not become visible under direct observation. Chaotic mixing, for example the spread of contamination in a drift, or the cream poured in the coffee, the mixing of paints, is an

exception. In these cases fractal structures become visible also in real space. This is the reason why we have chosen to utilize it in teaching chaos physics with the aid of handicraft. The photo in Fig.1. shows an example of chaotic mixing pattern: oil on the surface of water.

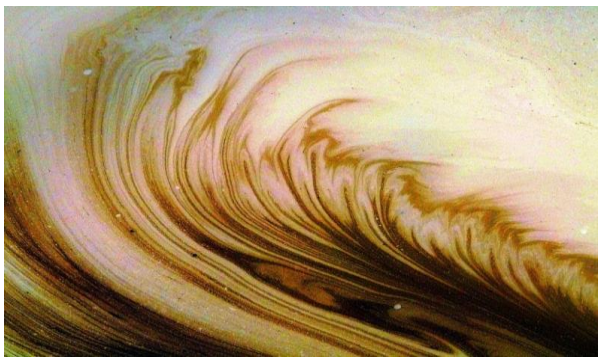

Fig.1. Oil on the surface of water (Photo: Traian Antonescu)

APPLIED TECHNIQUES (BASED ON CHAOTIC MIXING)

The following handicraft activities have been involved in teaching: painting paper, candles and eggs with marbling technique. The most important technique is marbling [8], which is chaotic mixing in two dimensions.

The steps of marbling technique are the following: 1. Small amounts of two or three different marbling paints are poured on the surface of water. 2. Marbling paint is mixed (Fig.2.a)) presents the mixing of paints). 3. A sheet of paper is placed on the surface. 4. The sheet is flattened against the surface using quick but definite movements so that it can get in full contact with the surface and the paint as Fig.2.b) indicates. 5. The sheet is grabbed and lifted up carefully as it is shown in Fig.2.c). 6. As a result, marvelous fractal structure becomes visible with nice Cantor-filaments.

Fig.2. a) Mixed paints on the surface of water, b) Sheet flattened against the surface of water, c) The painted sheet lifted, fractal filaments become visible on the paper

HOW HANDICRAFT ACTIVITIES HELP STUDENTS UNDERSTAND THE ESSENCE OF CHAOS

Chaotic mixing is the most essential, the most familiar and the most spectacular phenomenon of chaos. In one of the introductory classes we examined the spread of a paint drop or a drop of contaminant in a tank with two drain holes which is also an illustration of chaotic drifting. It is surprising that the drop changes its original shape in a very short time in a way that a well-defined fractal structure becomes visible meanwhile each particle describes its own chaotic path [6]. This structure is very similar to the patterns made by the students during the handicraft activities. Therefore, the aesthetic experience during handicraft activities is suitable to raise interest and to motivate students.

During painting with marbling technique students have the opportunity to gain experience with chaotic mixing phenomena. It is a guided experience: they observe with attention for the first time how fractal structure evolves during chaotic mixing. In Fig.3.a) we can see paints on the surface of water, which is actually the result of chaotic mixing, in Fig.3.b) we can see a part of a fractal filament patterned sheet made by the students. This is the imprint of chaotic mixing, which makes students understand this aspect of chaos physics.

Fig.3.a) Paint on the surface of water: chaotic mixing, b) Fractal filament patterned sheet: imprint of chaotic mixing obtained by the students with marbling

Structures similar to the fractal structures that become visible during the marbling activity appear in environmental flows, for example in the case of spread of contaminants. Students have the possibility to compare the pattern of their pieces of arts and the pattern of oil contamination on the surface of water (Fig.4.a)) or the pattern of foam pollutants before the dam as we see in Fig.4.b).

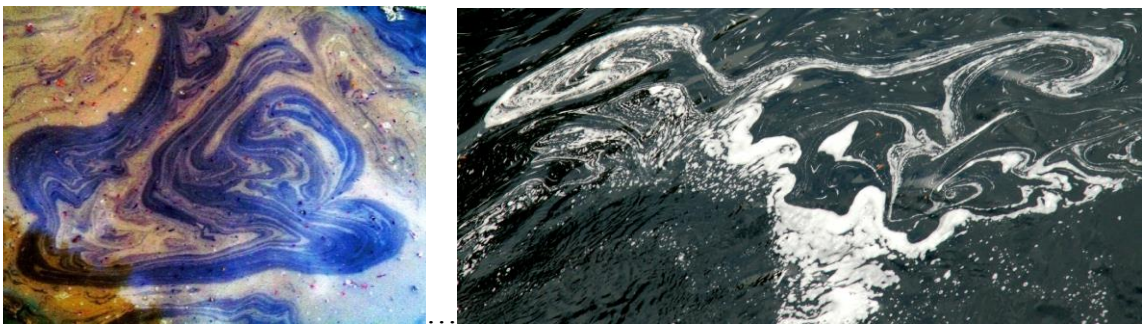

Fig.4.a) Oil contamination on a puddle (photo by Antonescu Traian),
b) Foam pollutants before a dam (photo by György Károlyi)

We aim to enhance students' competence of thinking in pictures: they will be able to recognize similar patterns in different phenomena. It is very important to note that these are not pictures of a virtual world, but patterns occuring in the natural environment.

The interesting experience related to the phenomenon will motivate students to get more deeply involved in the subject: if the experience is interesting, it will raise the curiosity of students to develop a computer program to model the phenomenon. This experience might raise motivation in students to gain the knowledge required for a deeper understanding of the phenomenon.

PAINTING EGGS, CANDLES AND PAPER WITH MARBLING TECHNIQUE

Other handicraft activities related to chaotic processes are the painting of eggs during Easter and the painting of candles during Christmas time. The steps of painting eggs are the following: 1. A stick is fixed inside a white egg so that it stays stable (blown eggs, or white plastic eggs are used); 2. The egg is fully immersed under the water. 3. Small amounts of paint (two or three different colors) are poured on the surface of water then mixed in order to have a beautiful pattern with fractal filaments. 4. The egg is taken out immediately but very slowly so that the paint is evenly distributed on its surface. 5. Care should be taken while drying the eggs (as you can see in Fig.5.a). As a result, marvelous fractal structures become visible with nice filaments as can be seen in Fig.5.b).

Fig.5.a) Drying the eggs, b) Fractal-patterned Easter eggs made by students

Before Christmas we paint candles with Cantor-filaments. The steps of painting candles with marbling technique are similar to that of painting eggs (Fig.6.).

Fig.6. Candles with fractal filaments painted before Christmas

CONCLUSIONS

The summary of the teaching unit described above that I have implemented and I find worth sharing is the following: First the teacher talks to students about chaos theory, the order appearing in phase space, the fractal structures. Then, students are familiarized with mathematical fractals. As a next step the teacher raises students' awareness that fractal structures become visible during chaotic mixing. Students have the chance to observe fractal patterns during mixing. During appealing handicraft activities students experience the process how the patterns develop and connect handicraft with chaotic phenomena.

The benefits of the teaching method can be summarized as follows:

Firstly**,** handicraft activities are suitable tools for raising students' interest in physics, more specifically in chaotic phenomena. Marbling gives opportunity to get to know the characteristics of chaos.

The fact that the interest of students has been successfully raised is proven by the number of students choosing chaos physics for their school project after participating in my chaos physics lessons, even students who are not considering to continue their studies in physics. Another indication is that several students have chosen fractal geometry or chaos physics as the topic of their optional presentation at physics class.

Apart from raising interest, hands-on activities are motivational tools for students who desire to obtain deeper knowledge of the chaotic phenomena, who would like to be able to mathematically describe the system or write a computer program for the simulation of the phenomenon.

Secondly, as we have already mentioned above, the aesthetic experience during handicraft activities is suitable for raising interest and motivating students. At the same time the handicraft activity in class, creation itself develops the visual and aesthetical view of students. Creating works of art, the process of mixing and experiencing the development of the pattern help to deepen students' understanding, and develop among others the competence of thinking in pictures. Aesthetic experience in class increases motivation in everyday school life.

Thirdly, we experienced that the students' interdisciplinary concept is largely strengthened during these lessons.

Finally, an important benefit related to the IBL method is the group collaboration where a platform is created for the development of friendship among students and the teamwork facilitates close contacts between students and tutors [7].

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