"Chaos" A New Elective Subject for High School Physics Students - Development, Implementation and Evaluation

Thesis for the Degree DOCTOR of PHILOSOPHY

Submitted to the Scientific Council of The Weizmann Institute of Science

Rehovot, Israel

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November 1999

Abstract

A new study unit in the subject of Choas, aimed at senior level high school students taking the advanced Physics program, was developed, implemented and evaluated.

Beyond its significance as a fascinating physical domains, this subject carries an important philosophical message: "Determinism" does not assure the possibility of prediction.

Our goal was to develop a study unit which broadens the physical worldview which students developed during the study of classical Mechanics, and helps them consolidate their previous knowledge in Mechanics.

Since no prior research examining student understanding of Chaos existed, we addressed the following questions:

1) What are the difficulties in comprehending the main concepts of Choas Theory for high school students?
2) How does the study of Chaos influence the organization of the mechanistic worldview of students, developed during their previous studies of Mechanics?

After we had trained teachers, the unit was taught twice. A formative evaluation study was conducted and followed by some content changes in the unit, and by the development of a computerized mode of teaching. In this mode, the students study individually with guidance of an expert in the field, without the intervention of their teachers.

The unit was taught for a third time to approximately 30 students, via an Internet system. The computerized unit incorporates current technological tools, including numerical simulations on one hand and browsing in related Internet web sites on the other.
The research results and conclusions are as follows:

Achievements and difficulties in understanding the main concepts in the field

a) From the list of goals we set when developing the unit, several were achieved successfully, so that after studying the unit, the student:
    1. Undertnd the concept of "sensitivity to initial conditions"

2. Recognize the characteristics of ordered motion and chaotic motion
3. Recognize mathematical and natural fractals
4. Can apply the concepts they studied to new phenomena

b) Several goals were achieved only partially, due to some difficulties that arose in the understanding of a few concepts. In particular:
   1. The differentiation between the concepts "Chaotic" and "Random" is not trivial. The formal definition of these concepts is not sufficient to enable the students to clearly distinguish between them.
   2. The concept of "deterministic" as "predictable" is very resistant to change. Even after the students know that there are deterministic systems, whose long term behavior cannot be predicted as a result of the system's sensitivity to initial conditions, they still have the naïve concept that the possibility of writing equations is equivalent to the possibility of prediction.
   3. The students recognize the period doubling scenario in the transition from order to chaos, and they can even succeed in solving problems which relate to this concept. However, there is some difficulty in the understanding of the concept of "global order."

These problems were related to the students' extent of readiness after studying Classical Mechanics.

The influence of the study of "Chaos on the mechanistic worldview of the students

Initially, after the instruction, students tended to over generalize the learned concepts. For example, they tended to think that all systems are chaotic. A clarification of the basic assumptions of the Newtonian Mechanics and its methods (formulating models for the purpose of prediction) helped solve this problem in subsequent teaching cycles. In addition, this helped to develop a more comprehensive view of the Newtonian Mechanics.

We found that the defect of learning Chaos on the mechanistic worldview was moderated. This was expected, since instruction only lasted 40 hours.

Teaching through a network

As a by-product, we have found that teaching this subject to willing high school students via computerized network has been very successful. It exposed the high school students to a different, efficient and exciting way of learning, which incorporated contemporary technologies.

Conclusions

Based on the above, we believe that in order to benefit from the study of this unit, students need to organize the prior knowledge that they have acquired in studying Mechanics. The methods we used, like instruction in simple numerical methods for solving physical problems, and discussion about the objectives (prediction) and methods (mathematical modeling) of mechanics seem to be helpful in this respect, and should be included in extended form in the regular mechanics in instruction section. Following this, teaching the unit in Chaos can help broaden the students'

general overview of Physics. Moreover, it can contribute to the consolidation of knowledge that was acquired in the study of Mechanics.