June 2023

STEAMTeach

Science | Technology | Engineering | Arts | Mathematics

PROBLEM-BASED LEARNING: CHAOS THEORY

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PROJECT

PROJECT ACRONYM	STEAMTeach
PROJECT TITLE	STEAM Education for Teaching Professionalism
PROJECT REFERENCE	2020-1-ES01-KA201-082102
START DATE	1st October 2020
KEY ACTION	Cooperation for innovation and the exchange of good practices
ACTION TYPE	Strategic Partnerships for school education

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Problem-Based Learning

Chaos Theory

Author	FÜLÖP Csilla Ph.D.
STEAM areas	Physics, math, languages, cuisine, technology, history, meteorology, IT, biology, geography, integrated science, chemistry
Cross-cultural connections:	Cuisine, origami, language skills, games, peonza game, fractals in nature, phenomena

Summary

Subject	Physics
Topic	Chaos theory
Age of students	Age 14–19 years
Project time	7 x 45 minutes
Number of participants	3-30 (preferably 8-12) students
Online teaching material	All the links are under the related content of the programme
Offline teaching material	All the links are under the related content of the programme
21st-century competences	Innovation, creativity, problem-solving, active learning, critical thinking, decision-making, presentation skills, content evaluation, discussion

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Learning objectives

Students can recognise chaotic phenomena in their everyday life and surroundings: food, flows, games, weather, biology, medical studies, etc.

They become familiar with the latest results of physics: methods of classical mechanics in a modern mathematical setting: the role of simulation, and the exponential nature of error propagation.

They will be able to rely on and use classical secondary physics: Atwood machine, pendulum

Students meet the basic notions of chaos theory and are introduced into

advanced mathematics and science: phase diagrams, simulation, use of IT, exponents, error propagation, etc.

Project Plan

	Procedure	Time
 Discussion questions	The history of chaos theory. Who studied chaos theory? Do we know any chaos theory scientists in our country? What is the central idea in chaos theory? Can we observe chaotic phenomena? What is the butterfly effect? Are there any chaotic games? Is chaos theory present in art (poems/novels/movies/visual arts, etc.)? Is chaos theory modern physics at all? Or is it classical physics? If it is classical physics, why is it physics of our age, then?	45 minutes

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	Chaos or instability? Which sciences use chaos theory? What is the connection between simulation and real-life phenomena?	
 Brainstorming	What do we know about chaos theory? What are chaotic phenomena?	
 Prepare	What topics do we revisit? What topics do we investigate? What online/offline information can we use? What tools do we need?	45 minutes
 Predict	There are experiments we can do. We can learn about the gist of chaos. …..	
 Plan	What content do we use to understand and what can we learn from chaos theory?	
 Explore	Investigating the aspects of chaos theory on a wide range of scales. Classical mechanics is about the special, rarely observable cases of motions. In-class science experiments of motions are not easy to demonstrate, they can go chaotic.	2 x 45 minutes

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Record

Record what material you worked with. Evaluate them. Give suggestions to other students interested in the topic.

Also record if you found them useful or not. Note why.

Demonstrate

Prepare a chaotic tea!

Practical exercises with plasticine.

Have fun with chaotic games

Lace and fractals (phase diagrams)

Hand-made fractals and fractals in nature.

2 x 45 minutes

Some areas that can be great examples:

Area 1. History

There are some students who find it easier to understand concepts if they are familiar with the historical background. It is worthy for all to find out what questions arose and when, how scientists made efforts to figure out the science behind phenomena.

Main steps of science towards chaos theory:

a) International level:

- Weierstrass
- Kovalevszkaja
- Carlwrigt & Littlewood
- Kolmogorov
- Lorentz

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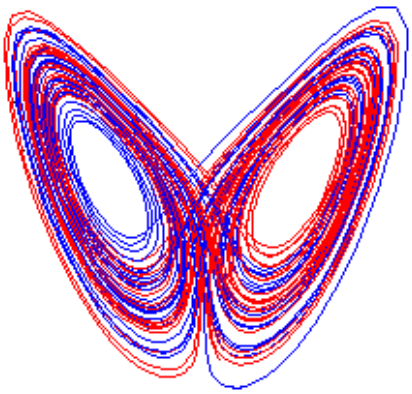

b) Hungarian aspects:

- KöMAL
- Vermes Miklós
- Szépfalussy Péter
- Vicsek Tamás
- Gruiz Márton
- Tél Tamás

Chaos theory - Wikipedia

What is chaos theory? | Britannica

Area 2. Basic notions

There are some basic notions that appear in most secondary curricula, yet very important in chaos theory.

We should study or revise these:

- Equilibrium (notion and types)

https://www.space.com/chaos-theory-explainer-unpredictable-systems.html

- Is a phenomenon a sequence of instabilities or a chaotic one?

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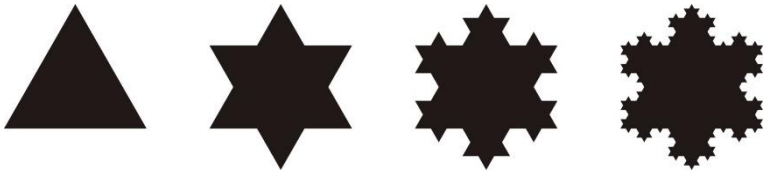
Life comes at u fast commercials 3 - YouTube

- the laws of classical physics

- error, error propagation

Area 3. (Applied) mathematics

-Fractals: the Mandelbrot set, the Carnot set, the Koch snowflake, the Sierpinsky mesh, the Menger sponge



Fun with Fractals - YouTube

Fractal - Wikipedia

Fractals are typically not self-similar - YouTube

- Fractals in nature: biology-flora, biology-fauna, geography, meteorology, etc.

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 -

How Chaos Theory Unravels the Mysteries of Nature - YouTube

Fractals in Nature - YouTube

Art: Origami: creating a fractal

Origami Fractal - Andrea's Rose Tutorial - YouTube

- The dimension of the fractal: 1D, 2D, 3D, $\log_a b$, factors, definition of quotient dimension, Poincare map

Area 4. Chaotic experiments

- "Similabda", the Hungarian yo-yo
- yoyo
- pendula
- chaotic sculptures

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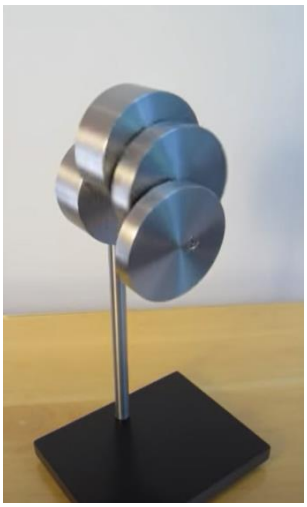

- The magnetic pendulum
- Chaotic watch
- Non-harmonic oscillator
- Smoke
- Chaotic water mill
- Induced oscillation

Triple Pendulum Chaotic Acrobatics - YouTube

Rott's Chaos Pendulum - YouTube

3A95.50 Double Pendulum Ring and Bar - YouTube

PH ME DY DEMO 70045A V0521 Triple Pendulum Some Chaotic Behaviour - YouTube

3D Triple Pendulum - YouTube

Ferrocumulus Chaotic Pendulum - YouTube

ROMP: Randomly Oscillating Magnetic Pendulum - YouTube

Gentry Stein - 1st Place - 1A Final - 2019 US Nationals - YouTube

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Double Pendulum Chaos Light Writing (computer simulation) 1 - YouTube

Chaotic Lorenz Water Wheel - YouTube

Chaotic Pendulum with Magnets - YouTube

Area 5. Chaotic activities

Chaotic tea:

marble cake & coffee with cream

Chaotic activities:

- Plasticine
- Rubber ball in a bowl
- The Ebru technique

How to paint on Water for Paper Marbling and Ebru Art. - YouTube

Water Marble Nail tutorial (for beginners) - YouTube

Tırnağa Ebru Sanatı Nasıl yapılır - YouTube

Area 6. The wide palette of uses

- The solar system

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- Meteorology
- Flow
- Drift
- Self-oscillation
- Feedback in electric circuits
- Biochemical processes
- The operation of the heart
- The operation of the brain
- Dynamics of population
- Random number generation
- Encryption
- Ball games
- Modelling economic processes
- The operation of the mixer
- The process of kneading dough

Area 7. IT

- The Atwood machine
- The mathematical pendulum
- The polar coordinate system
- Simulation
- Dynamics Solver
- Different solutions: chaotic & periodic ones

Trajectories of the Swinging Atwood's Machine - YouTube

Reflect

What material was useless for you? Why?

What did you learn?

What did you find interesting?

What ideas were reinforced?

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What ideas had to be overridden?

Present the result of your investigation.

It can be a game, an artistic activity, a presentation, a crossword, an experiment, a video, etc.

Presentation

Product

- Marble cake with coffee
- Yoyo
- Ppt
- Video
- Hand-out
- Poem
- Origami
- Nail polish
- Painting with ebru technique
- Origami fractal
- Sponge

Re-design

Overview the notions and methods that we used. Evaluate them. Suggest or substitute.

45 minutes

Stations

Science station

- Solar system
- Hydrodynamics
- Gyroscope
- Experiment
- Error and error propagation
- Phase diagram, ljapunov exponent
- Fractals

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- Equilibriums: stable, neutral, instable, chaotic
- Magnetic pendulum
- Swinging atwood machine
- Ball in a bowl

Research station

- Problems to investigate in science history: Poincare, Kovalevskaya, Kolmogorov, Lorentz, etc.
- Map the fields in which chaos is used (astronomy, meteorology, drift, flow, vibration, swelling of electric circuits, brain and heart phenomena, chemical and biochemical processes, population dynamics, encryption, random and accidental phenomena, economics, ball games, etc.
- Modern mathematics, numerical methods, fractals, dimension
- Order in chaos
- Chaos in art: movies, videos, promotional clips and articles

Technology station

We highlight active pedagogy, and promote hands-on, minds-on didactics in problem-based learning as well.

There are a number of possible solutions in this field, too, such as pendula, toys, manicure, yoyo, food, origami, graphs, tools for experiments, etc.

IT-related

- PC
- Smartphones
- Digital cameras
- Internet
- Dynamics Solver
- YouTube

Other

- Scissors
- Rulers
- Blank paper
- Graph paper
- (coloured) pencils
- Markers

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- Yo-yos
- “similabda”
- Baby bouncers
- Cigarettes
- Matches
- Bowls
- Rubber balls

Engineering station

- Radio locator
- Chaotic watch
- Pendula: magnetic, double

Tools and materials

- Calculators
- PC
- Internet
- Graph paper
- Rulers
- Pencils
- Magnetic pendulum: button magnets, wooden rod and slab, glue, markers

Art and Design station

- Poems, novels, jokes, anecdotes, etc.
- Ebru technique
- Melange
- Origami
- Manicure
- Fractal art

Tools and materials

- Paper and pen or video recorder
- Water, bowls, paint, cloth or wooden yo-yos
- Plasticine

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- Origami paper
- Scissors
- Nail polish, nail polish remover, cotton wool, small bowls, water

Math station

- Hand-outs
- Maps
- Calculator
- PC, laptop, or smart phone
- Paper, markers

Recording station

- Paper, pens or pencils (different colours)
- Digital cameras
- PC or laptop
- Smartphones

Experiences

Chaotic phenomena can be observed in our everyday life.

These have not been scientifically described until the 20th century.

Chaos theory is based on classical physics but is a present-day topic for investigation.

Chaos is used in a very wide range of scientific and artistic fields.

Appendix

1 Káoszelmélet (fizikashow.hu)
2 Az osztályozás és a káoszelmélet (oszk.hu)
3 A káosz természetrajza (termeszetvilaga.hu)
4 Pillangóhatás (elmélet) – Wikipédia (wikipedia.org)
5 Káoszelmélet – Wikipédia (wikipedia.org)
6 meszena_magyar.pdf (elte.hu)

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7 DOKTORI ÉRTKEZÉS TÉZISEI (elte.hu)

8 DOKTORI ÉRTKEZÉS TÉZISEI (elte.hu)

9 Szegedi matematikusok rendet tesznek a káoszban | National Geographic (24.hu)

10 Microsoft Word - Szatmary-Bajko (atw.hu)

11 Szatmáry-Bajkó Ildikó: „Káoszt”? – Azt! – Káoszelmélet a középiskolában, Fizikai Szemle, LVI, 376, 2006/11.

12 Gruiz Márton: A kaotikus mechanika kapcsolata Platónnal és a levelestésztával, Természet Világa, 129, 389,1998.

13 Fraktál – Wikipédia (wikipedia.org)

14 Fraktálművészet – Wikipédia (wikipedia.org)

15 Mandelbrot TDK - Mi a fraktál? (fizikashow.hu)

16 Index - Tudomány - Káoszelmélet fejti meg a változócsillagok évszázados titkát

17 http://fiztan.phd.elte.hu/letolt/fraktalok_vilaga_nagy.pdf

18 leave two empty, 16 pt single lines (elte.hu)

English sources:

1 Chaos theory - Wikipedia

2 Chaos: The Science of the Butterfly Effect - YouTube

3 How Chaos Theory Unravels the Mysteries of Nature - YouTube

4 An Unpredictable Universe: A Deep Dive Into Chaos Theory | Space

5 What is chaos theory? | Britannica

6 Fun with Fractals - YouTube

7 Fractal - Wikipedia

8 Fractals are typically not self-similar - YouTube

9 What is a Fractal? - The Ultimate Guide to Understanding Fractals (iternal.us)

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10 ED413289.pdf

+ variety of pictures, videos from the Internet

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