

D3.1.x Clocks and Gears

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Author: Maria

Pavlidou

Contributors:

Lynne Long,

Kostas

Nikolopoulos

Approved by:



Table of Contents

1	Introduction / Demonstrator Identity.....	3
1.1	Subject Domain.....	3
1.2	Type of Activity	3
1.3	Duration	3
1.4	Setting (formal / informal learning)	3
1.5	Effective Learning Environment.....	3
2	Rational of the Activity / Educational Approach	5
2.1	Challenge.....	5
2.2	Added Value	5
3	Learning Objectives	6
3.1	Domain specific objectives.....	6
3.2	General skills objectives	6
4	Demonstrator characteristics and Needs of Students	7
4.1	Aim of the demonstrator	7
4.2	Student needs addressed	7
5	Learning Activities & Effective Learning Environments	8
6	Additional Information	15
7	Assessment.....	16
8	Possible Extension	17
9	References.....	18

1 Introduction / Demonstrator Identity

1.1 Subject Domain

How mechanical clocks use gears to control the speed of movement of the hands.

1.2 Type of Activity

School or University based – national UK

1.3 Duration

2 hours up to half-day

1.4 Setting (formal / informal learning)

- Starting formal: introductory talk in classroom or lecture theatre (in school or at the University)
- Continuing informal: group work in classroom (in school or at the University)

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** class works together during the workshop;
- **Arts-based:** the construction of the clocks uses creative skills and the ability of students to follow diagrammatic guidelines
- **Dialogic space / argumentation:** through questioning and dialog students are allowed to express their ideas on how ancient clocks work by looking at drawings and videos
- **Visits to research centres (virtual/physical):** groups of students can visit the University of Birmingham and complete the workshop in the University premises. As part of this visit students will be given a tour of the campus and they will have the chance to speak to undergraduate students about university life.
- **Communication of scientific ideas to audience:** the workshop allows students to understand how by using gears we can do mathematical calculations and control the speed of the hands. This can be extended to talk about astronomical clocks, the

Antikythera Mechanism and how analysing the gears of the Mechanism gives us detailed information about the astronomical knowledge of the ancient Greeks.

2 Rational of the Activity / Educational Approach

2.1 Challenge

The young generation lacks basic knowledge when it comes to simple machines such as levers, gears etc. To address this problem the current UK curriculum has introduced gears in year 5 of the primary science curriculum. We hope that this workshop will deliver the topic of gears in a fun way and that it will also extend the knowledge of the students to understand how mechanical clocks use gears to control the movement of the hands and the mathematics that describes this.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The workshop aims to extend the knowledge of the students to understand:

- how scientists use this knowledge to reveal the astronomical knowledge of ancient civilisations
- how groups of multi-disciplinary scientists are needed in analysing ancient machines
- how science and maths can help historians and archaeologists in their work.

The final stage of the clock-making workshop will allow students to learn the idea of instrument calibration by allowing them to alter the length of the clock pendulum and make the clock as accurate as possible.

3 Learning Objectives

3.1 Domain specific objectives

The main objectives of the workshop are:

- To understand that clocks evolved through time, starting with simple water/sand clocks and slowly moving on to clocks with gears
- To understand that when an object rotates there are two speeds we can refer to, the linear and the angular
- To understand that two gears can be linked in two different ways: through the same axle or via a common point along their circumference
- To understand that the size of the gear (radius and number of teeth) is directly linked to how a gear will rotate relative to another
- To understand that the rotation of gears can be accurately described by mathematical equations
- To understand that the period of oscillation of a pendulum varies with its length and that this is used to calibrate the clock to work accurately

3.2 General skills objectives

The general skills acquired or improved by the workshop are:

- To understand how equations can describe accurately the movement of objects
- To be able to understand how simple machines work by looking at their diagrams
- To improve dexterity by making a clock
- To understand how science can help reveal secrets from the past i.e. astronomical knowledge of ancient civilisations
- To understand how scientists work within a multi-disciplinary group where each member is an expert on their field

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the demonstrator is to use a creative way to introduce the concepts of gears and how they are used in mechanical clocks, to a younger audience.

4.2 Student needs addressed

The list includes:

- Satisfy curiosity on how clocks work
- Engaging in fun group activity (making clocks) that has a clear educational purpose
- Kinaesthetic approach to the learning of the concepts of gears and their equations (using their bodies as rotating gears)
- Understanding of how science works: the importance of using an accurate instrument for measuring time and how to achieve this

5 Learning Activities & Effective Learning Environments



Science topic: **Gears**

(Relevance to national curriculum)

Class information

Year Group: **5**

Age range: **9-10**

Sex: **both**

Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) **all inclusive**

Materials and Resources

What do you need?

- **Introductory power point presentation on clocks and gears**
- **Materials for making clocks**
- **Stopclocks and rulers to calibrate clock**
- **Paper, pencil to keep record of clock accuracy**

Where will the learning take place? **In school or at the University**

On site or off site? **On site**

In several spaces? (e.g. science laboratory, drama space etc), or one? **In a room that can facilitate lecture and group work**

Health and Safety implications? **Must have plenty of space when students emulate gears with body movements**

Technology? **Projector for power point presentation**

Teacher support? **Yes. To encourage and help as necessary**

Prior pupil knowledge

none



Individual session project objectives (*What do you want pupils to know and understand by the end of the lesson?*)

During this scenario, students will

- Listen to the introductory talk and answer questions about how ancient clocks work by looking at diagrams, videos or photographs
- Engage in gear-rotation demonstrations using their bodies (groups of various student numbers make circles holding hands and rotate against each other)
- Construct a clock (in groups of two) by following guidelines which are given to them as a diagram only
- Calibrate their clock by altering the length of the pendulum of the clock and by taking measurements of the clock accuracy at different lengths

Assessment

Questioning and dialog through all sessions as well as through final session

Differentiation

How can the activities be adapted to the needs of individual pupils?

The clock-making exercise will be the most challenging part of the workshop. Groups that struggle will get help but there will be a small number of groups that will take longer to complete the clock and therefore will not have time to calibrate it.

Key Concepts and Terminology

Science terminology:

gears, mathematical equations, ratios, astronomical clocks, Antikythera Mechanism, calibration, accuracy

Arts terminology:

Model making, body-movement

Session Objectives: During this scenario, students will link the use of gears to mathematical calculations and how this controls the speed of rotation of clock hands.



Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONS Features	Student	Teacher	Potential arts activity
<p>Phase 1:</p> <p>QUESTION: students investigate a scientifically oriented question</p>	<p>Students pose, select, or are given a scientifically oriented question to investigate. <i>Balance and navigation</i> through <i>dialogue</i> aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through <i>dialogue</i> between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through <i>dialogue</i> with different ways of knowledge inspired by <i>interdisciplinarity</i> and personal, embodied learning. <i>Ethics and trusteeship</i> is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.</p>	<p>Students engage with teacher's questions, watch power point presentation and demos and try to interpret the movement of various mechanisms through drawings or videos.</p>	<p>Workshop leader will use challenging questions, pictures, drawings, videos and demos involving the students to attract the students' interest in the movement of gears and its link to mathematical equations.</p>	<p>None at this stage</p>



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<p>Phase 2:</p> <p>EVIDENCE: students give priority to evidence</p>	<p>Students determine or are guided to evidence/data, which may come from <i>individual, collaborative and communal activity</i> such as practical work, or from sources such as data from professional scientific activity or from other contexts. <i>Risk, immersion and play</i> is crucial in <i>empowering</i> pupils to generate, question and discuss evidence.</p>	<p>Students participate in body-simulation of rotating gears. They gain an insight into the movement of gears and the link between number of teeth and rotating speed.</p>	<p>Workshop leader will question students to ensure links between observations and conclusions are understood.</p>	<p>Group body movement to simulate rotating gears.</p>
<p>Phase 3:</p> <p>ANALYSE: students analyse evidence</p>	<p>Students analyse evidence, using <i>dialogue</i> with each other and the teacher to support their developing understanding.</p>	<p>Students think and decide how many classmates should there be in a circle in order for the circle to rotate faster/slower relative to another circle. Students test their hypothesis by trialling their ideas.</p>	<p>Workshop leader will pose questions that link the number of teeth in a gear (number of students in a circle) and its relation to the speed of rotation.</p>	<p>Group body movement to simulate rotating gears.</p>
<p>Phase 4:</p> <p>EXPLAIN: students formulate an explanation based on evidence</p>	<p>Students use evidence they have generated and analysed to consider <i>possibilities</i> for explanations that are original to them. They use argumentation and <i>dialogue</i> to decide on the relative merits of the explanations they formulate, <i>playing</i> with ideas.</p>	<p>Students will be asked to explain why is it that if the number of teeth in a gear doubles this results in the speed of rotation being halved etc.</p>	<p>Workshop leader will give help by asking them to think about the length of the circumference relative to the number of teeth.</p>	<p>None at this stage</p>



<p>Phase 5:</p> <p>CONNECT: students connect explanations to scientific knowledge</p>	<p>Students connect their explanations with scientific knowledge, using <i>different ways of thinking and knowing</i> ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to <i>interdisciplinary</i> knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.</p>	<p>Discussion follows between workshop leader and students where the idea below is derived: that doubling the teeth doubles the circumference and therefore at the same time the speed will be halved.</p>	<p>Workshop leader drives the discussion to reach the conclusion that doubling the teeth doubles the circumference and therefore at the same time the speed will be halved.</p>	<p>None at this stage</p>
<p>Phase 6:</p> <p>COMMUNICATE: students communicate and justify explanation</p>	<p>Communication of <i>possibilities</i>, ideas and justifications through <i>dialogue</i> with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be <i>immersed</i> in a key part of the scientific process. Such communication is crucial to an <i>ethical</i> approach to working scientifically.</p>	<p>Students choose a partner to work on constructing a clock.</p>	<p>Workshop leader emphasizes the importance of choosing a partner not based on friendship but based on skills that the first student does not have so that the team becomes stronger.</p>	<p>None at this stage</p>

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<p>Phase 7:</p> <p>REFLECT: students reflect on the inquiry process and their learning</p>	<p><i>Individual, collaborative and community-based</i> reflective <i>activity for change</i> both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.</p>	<p>Students make a clock, in groups of 2, following diagrammatic instructions.</p>	<p>Workshop leader will help students as and if needed.</p>	<p>Model building.</p>
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6 Additional Information

The clock-making exercise uses the product:

https://www.amazon.co.uk/Tobar-Make-Your-Own-Clock/dp/B0039ZMZGK/ref=sr_1_6?ie=UTF8&qid=1470657253&sr=8-6&keywords=clock+making



7 Assessment

Short term gained knowledge is assessed throughout the workshop by posing questions and at the end via a written feedback questionnaire.

Long term gained knowledge will be assessed through written feedback which will be sent to students a month after their participation.

Teacher feedback questionnaire will also be used at the end of the workshop.

8 Possible Extension

After trialling this workshop we will re-evaluate the resources and decide on possible extensions or alterations.



9 References

The Antikythera Mechanism Research Project: <http://www.antikythera-mechanism.gr/>

Dave Goodchild's model of the Antikythera Mechanism:
https://www.youtube.com/watch?v=Ke_wspU5748

Museum of the Ancient Greek Technology: <http://kotsanas.com/gb/>

