INTERACTIVE WORKSHOPS, GAMES, AND SOFTWARE: EXERCISES IN ENVIRONMENTAL EDUCATION

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Summary

This chapter presents some exercises for environmental education showing the roles suggested for the teachers and students in the process. In the first two exercises, a link is made between mathematical calculations and the interpretation of the results in real life. In exercise 1, the mathematical technique of integration is used to calculate the impact of an environmental catastrophe on the surroundings, and the students are asked to decide what to do with the results.

In exercise 2, logarithmic calculations are used to draw conclusions about noise. In both cases, it appears that the value of the exact calculations is much less than it may appear at first glance.

In the third exercise, a small statistical investigation is to be performed with respect to

temperature rise and the greenhouse effect.

The fourth exercise is meant as a preparation on the introduction of the LCA (Life Cycle Assessment) method. Also, it prepares for sustainable product design, which implies that totally different aspects (such as technical quality, cost prize and the environmental impact) have to be considered together in order to design the optimal product.

In the fifth and sixth exercise, students are asked to discuss the subject of energy production and consumption in a critical way. The fifth can be used to confront students with preoccupation with certain aspects. The sixth may be useful to explain the rebound effect.

1. The Draining Accident Exercise

This exercise may be used in first year university, with the aim of bridging the gap between mathematics and other aspects of real life. It can be used in courses of mathematics, physics, chemistry, as well as technological and econometric courses. The best moment to use the exercise is shortly after the math subjects of integration has been treated.

The best way of making the exercise is to give a group of four to ten students the opportunity to do it as a group, with a teacher functioning as a tutor or coach, who is present with each group session.

A good way of handling the exercise would be:

In a first group session, the students receive the exercise on paper. They take some time to read it, and then discuss it for perhaps 15 minutes. Then, each student tries to solve the first and the second question individually. When this is done, the group discusses the calculations and the outcomes.

As a preparation of the third and fourth question, they can try to agree on steps to take, and divide tasks.

Some time later, a week perhaps, they come together again and inform each other of the findings. Then, conclusions are drawn with respect to question 3, and a set of instructions for the press officer (question 4) is made by the group as a whole.

A report is written by one or two group members, and handed over to the teacher.

1.1. Students' Role in the Draining Accident Exercise

A factory in which PVC is produced has a licence for the drainage of waste water in a nearby river. This licence is actively used, because on a certain summer day drainage takes place with a flow rate of 4000 litres per minute.

The quality of the flowing water is checked regularly, and as a result an alarm is given when at the moment of 12.31 it is discovered that in the outflowing water a substance is present which is highly toxic, and which certainly should not be appear in the surface water.

The substance is ***methyl-mercury-ethanolate*** (C_3OHgH_8; see Figure 1). The concentration of the toxic substance in the drainpipe is 3 ppm.

Immediately after the alarm, action is taken to close the valve of the drainpipe. This valve is a large and heavy gate. At 12.38 the valve begins to move. At first the movement is slow, because the heavy valve is hard to set in motion. After this slow start, most of the closing manoeuvre proceeds with a fairly high speed, but the last part is going slower again, since the drainpipe could be damaged if the valve closed with a bang. At 12.43 the valve is closed.

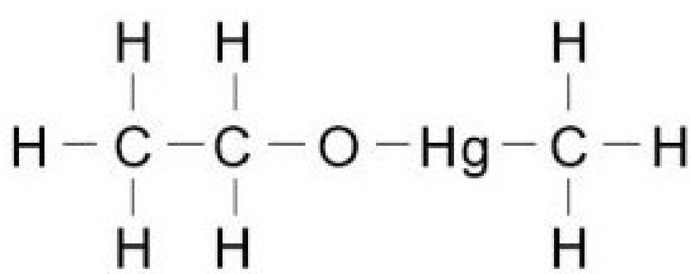

Figure 1: The molecular structure of methyl-mercury-ethanolate

During the closing operation, the curve of the flow rate of the water has a shape which resembles the graph of a sine function (see Figure 2).

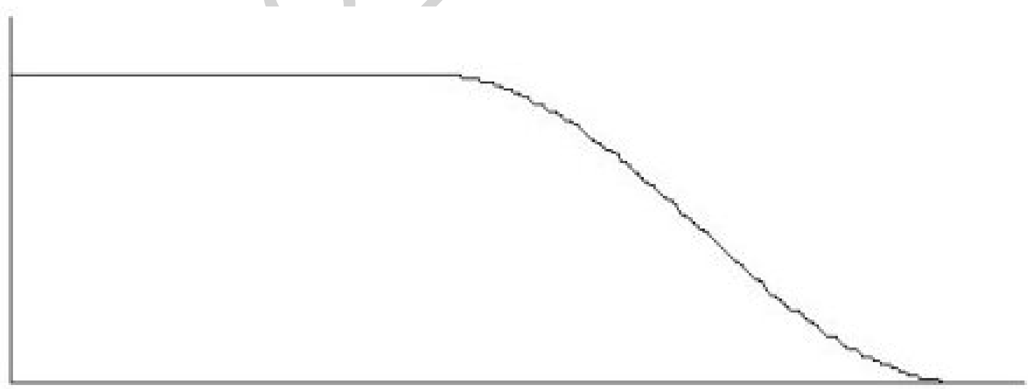

Figure 2: The flow of the water as a function of time.

Questions:

a) How many grams of the toxic substance have *at least* flown into the environment?
b) And how many grams *at most*?
c) What activities may have taken place between 12.31 and 12.38?
d) If you are the management of the factory, what instructions do you give to the press

officer of the company?

1.2. Teachers' Role in the Draining Accident Exercise

This exercise is meant to offer to the students a range of different aspects of a case.

The first of the four questions is a problem that, though not very easy for some (due to the mathematical character), is rather straightforward, and can be answered by using a well known algorithm.

The second seems to be of the same character, but it appears to be quite different.

The third question has a business character, and the fourth has to do with ethical as well as PR matters. Both these questions force the students to look at the outcome of their calculations and investigate the real meaning of the data they found.

Question 1:

The graph of the flow during the closing of the valve can be described as a cosine function (see Figure 3):

$$\Phi(t) \quad = \quad \dot{V}(t) \quad = \quad 2000 + 2000 \cdot \cos\frac{\pi}{5}(t-38) \qquad t \in [38\,;43] \qquad (1)$$

Alternatively, a sine function can be used, for instance

$$\Phi(t) \quad = \quad \dot{V}(t) \quad = \quad 2000 + 2000 \cdot \sin\frac{\pi}{5}(t-29.5) \qquad t \in [38\,;43] \qquad (2)$$

The outflow in the period of 38 till 43 min. is (using the cosine function):

$$\begin{aligned} V \quad &= \quad 2000 \cdot \int_{38}^{43} \left(1+\cos\frac{\pi}{5}(t-38)\right) dt \\ &= \quad 2000 \cdot \left[t + \frac{5}{\pi}(t-38) \right]_{38}^{43} \\ &= \quad 2000 \cdot (43+0-38-0) \\ &= \quad 10000 \text{ L} \end{aligned}$$

By the way, this calculation can easily be done without an integral. Thanks to the symmetry of the cosine function, in the interval [38; 43] the average height of the graph is half the maximum height, i.e. 2000: so V = 2000. (43 - 38) = 10000 L.

In the interval before that, from 31 min, a quantity of 4000. (38 - 31) = 28000 L

flowed out of the pipe.

In total therefore the outflowing volume is 28000 + 10000 = 38000 L, which is roughly equal to 38000 kg, since the water contains only a very small addition of other substances.

The concentration of the toxic substance was 3 ppm; so

$$m = \frac{3}{1000000} \cdot 38000\ \text{kg} = 114\ \text{g}$$

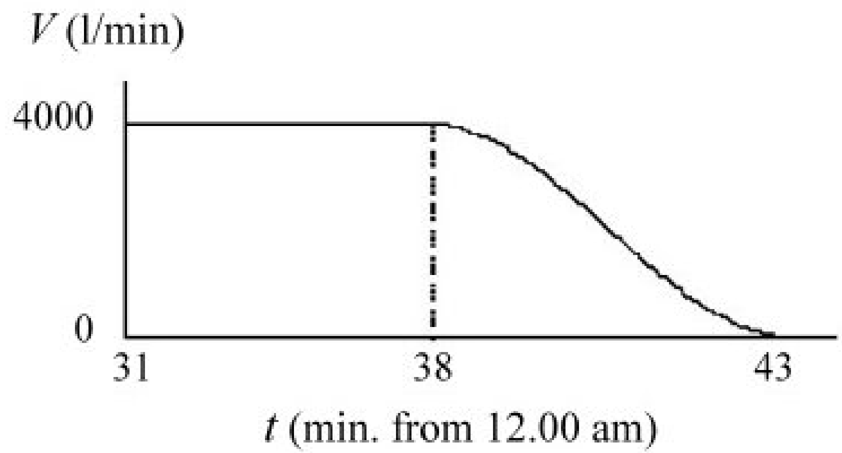

Figure 3: The water flow as a function of time, quantified

If you want, you can “argue” this number a little bit “down” by assuming that the moments, expressed as whole minutes, are in fact round offs of such data that the real time interval was (almost) 1 minute less. (For example from 12.31 min and 29.9 sec. till 12.37 min. and 30.1 sec). In that case the resulting mass would be m = 102 g.
(Although formally correct, this looks a bit like manipulating the results!)

Regarding the insecurity in the measurements, this “trick” is not even necessary, and the conclusion should be that at least about 100 g of methyl-mercury-ethanolate came into the surface water.

Question 2:

It is impossible to calculate how much has reached the environment at most.

The leak was discovered at 12.31; but there are no data about at what earlier time a check has taken place. The quality of the outflowing water was measured “regularly”. If this means, for instance, once a day, an enormous mass of poison could be flown out.

For students, this is a rather unfamiliar situation. Usually they are asked questions that can be answered by exact methods. The experience of simply not being able to perform the necessary calculations appears to be quite shocking for some of them; nevertheless, this situation is in fact all too realistic in many cases.

The students tend to *assume* certain data, in order to be able to answer the question. The teacher should see to it that they don't do this; of course it would be rather corrupt to give instructions to the press officer, based upon data that simply have been created by fantasy.

Question 3:

As towards the activities that may have taken place between 12.31 and 12.38: in those 7 minutes a lot of internal communication and decision making must have been going on. The students are invited to use their imagination on this.

Perhaps they can talk or phone to some managers in real production plants, to get some ideas.

Question 4:

Of course, there isn't only one correct answer to this question. The students should be judged, not with respects to their answers but to the motivation of their answers.

In formulating instructions for the company's press officer, relevant aspects are at least:

- the company's continuity;
- the choice between truth and lies, including the chance of being "caught" in telling lies;
- the ethical aspects of the situation;
- the public relations of the company, to the customers as well as to the people living in the neighbourhood; and
- the real care for the environment and the health of the people.

2. The Production Capacity Enlargement Exercise

Calculations are asked to investigate the chance for a factory of getting a license to enlarge its production capacity. In order to do this, students have to use logarithms; therefore, a good moment for this exercise is shortly after the introduction of the log-function.

The question that is literally asked, will appear to be a wrong question. So, the non-too-critical students are fooled. This may perhaps not be very friendly, but it is a very good and important learning step: in real life, it happens very often that the wrong questions are asked. It will be up to the future graduates, i.e. the students, to discover the (in) correctness of the questions they are asked, and it will be better if they learn this dureing their education course than afterwards.

2.1. Students' Role in the Production Capacity Enlargement Exercise

Somewhere in the countryside there is a production plant. In the halls there is some heavy machinery, with a total power of 200 kW. They produce rather a heavy noise, which can be heard quite well in the surroundings: at a distance of 1000 meter, where the outskirts of the nearest town are situated, the volume of the sound is 30 dB when the factory is operating on full power. This is no problem, since local environmental regulations indicate that the maximum sound volume is allowed to be as high as 36 dB.

Now, the factory wants to enlarge it's capacity: it wants to add new machinery, in order to enlarge the production of the same kind of products it was manufacturing up till now. The company is planning to raise the total machine power to 500 kW.

At the very moment the plans are completed, an announcement is received from the local government that the development plan of the nearby town is going to be changed: a new suburb will be built, because of which the distance between it and the factory will become only 600 meters.

Question:

What do you think: does the factory have a chance to receive a licence to enlarge its machinery according to the plans? (You only have to look at the sound aspects of the environmental regulations.)

2.2. Teachers' Role in the Production Capacity Enlargement Exercise

2.2.1. Theory

Relevant variables and formulas regarding sound:

- P is the power of the sound at the source, in watt.
- The *sound intensity* I in W/m^2, is calculated with:

$$I = \frac{P}{4\pi\, r^2} \text{ for pointlike sources} \qquad (3)$$

$$I = \frac{P}{4\pi\, r^2} \text{ for line shaped sources (e.g. a road)} \qquad (4)$$

in which h is the length of the source.

- The subjective experience of the sound is the *sound intensity level* L, in dB:

$$L = 10 \cdot \ln \frac{I}{I_0} \quad (dB) \qquad (5)$$

Here, I_0 is the reference intensity with a value of 10^{-12} W/m^2. For a human being, sound at this level is at the threshold of hearing, so all sounds below this level will not be heard.

2.2.2. Theoretical Calculation

The calculation can be performed, if two assumptions are made:

1. The sound intensity (in watt) is proportional to the total power (in watt) of the machinery;
2. The sound intensity (in watt) is inversely proportional to the square of the distance to the source of the sound.

The correctness of these assumptions will be discussed later; first, the calculations will be made.

The present sound level at a distance of 1000 m is 30 dB = 3 bel. The sound intensity (in an arbitrary unit) is therefore: $I = 10^3 = 1000$.

So, at a distance of 600 m the sound intensity is:

$$I = \left(\frac{1000}{600}\right)^2 \cdot 1000 \quad = \quad 2777.78$$

When the machine power rises form 200 kW to 500 kW, the sound intensity will grow to:

$$I = 2777.78 \cdot \frac{500}{200} \quad = \quad 6944.44$$

The sound level will then be:

$$\log 6944.44 \quad = \quad 3.8416 \text{ bel} \quad \approx \quad 38.4 \text{ dB}$$

Based on this number, which is higher than the limit of 36 dB, it will have to be expected that the new license will not be received.

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Bibliography

This article does not require a Bibliography.

Biographical Sketch

Mr. Niko Roorda received his Bachelor's degree in Astronomy from the University of Leiden in the Netherlands, and his Masters degree in Theoretical Physics and Philosophy from the University of Utrecht, also in the Netherlands. He worked as a teacher in secondary and academic education until 1998, and managed the department of Sustainable Technology at the Brabant University for Professional Education in the Netherlands. During 1999 and 2002 he was the project manager of the *Cirrus Project*, which pioneered the integration of sustainable development into the education and organization of the Polytechnic Faculty of the Dutch Avans University. For this he was awarded the Dutch National Award for Innovation and Sustainable Development in 2002.

Since 2000 he has also been working for the Dutch National Foundation for Sustainable Higher Education (DHO). For the DHO he developed the "AISHE", which is a tool for assessing the rate of integration of sustainable development into the education and organization of educational programmes of universities. This tool has been used in the Netherlands, Belgium and Sweden. He has published widely, including two textbooks, on sustainable development in higher education. As a DHO consultant, Mr. Roorda has been assisting and advising universities in their efforts to introduce and integrate sustainable development into their programmes. He also trains AISHE auditors and teachers.