Title: Parking Lot

Topic: Students explore through various interdisciplinary activities the mathematics and science topics involved in designing a parking lot.	**Time**: 4 x 45 min lessons	**Age**: Grade 5-9, 11-15 year olds

Differentiation

Lower level

The basic outcome of pupils is to develop an understanding of the need for ventilation in underground facilities. Students are also expected to produce some simple designs of the parking facility.

Higher level

Students can develop more complex models of the parking facility, taking into account all project constrains and trying to make the maximum profit (provide a safe design for the maximum number of cars).

Guidelines, ICT support etc.

- Problem / Key question: *What is the best possible design for an underground parking facility*?
- Students work in groups to answer the key question, while making sure their design is safe enough (provides enough space for cars), and can facilitate the maximum number of cars. Students will also estimate the requirements on ventilation.
- A video can be used to introduce students in the design of an underground parking facility. https://www.youtube.com/watch?v=-UgHwU9oGno
- Pupils work in groups of 3-4.
- Students can use Geogebra (or any other dynamic geometry software) and spreadsheet software in developing their solutions/designs.

Equipment needed for this activity

- worksheets for students
- computers with internet connection
- computers equipped with Dynamic Geometry software (like Geogebra), and spreadsheet software (Excel, Google Sheets, or any other spreadsheet software)

Required knowledge:

- elementary arithmetic operations
- scale
- simple functions

Health and Safety:
No special requirements

Learning outcomes for this activity
All:

All students are expected to understand the basic requirements of an underground parking design, and the necessity for fresh air supply.

It is also expected that all students will be able to develop a simple design for the underground parking facility.

Most:

Most students are expected to develop at least one appropriate underground parking design, taking into consideration all constrains (e.g, pillars and lanes). Students are also expected to develop calculation models for the parking facility cost depreciation.

Some:

Some students are expected to provide solutions that can facilitate the maximum number of cars.

Some students are also expected to develop more sophisticated depreciation and air supply models, using spreadsheet formulas (and other functions).

Lesson description

Starter Activity

During the first part of the activity students can work individually to read the provided introductory text and answer the readiness questions (Worksheet 1). The purpose of this starter activity is to introduce students to the context of the situation, and to familiarize themselves with the requirements of the underground parking facility.

Main Activity

Students form groups of three to four. During the main activities (Worksheets 2, 3) students work in their groups to solve the problem. However, each student is provided with his/her own worksheets. Each group works on the problem under the supervision of the mathematics and science teacher. Appropriate feedback and support (to overcome difficulties) is provided when needed.

In the second activity (Worksheet 2) students work in designing a working solution for the underground parking facility. After developing a first solution, students are encouraged to further improve their work, by taking into consideration the various extra requirements mentioned in the tasks in the second activity.

In activity 3 (Worksheet 3) students are encouraged to develop an algebraic solution for calculating (and using in the context of their design/solution) the fresh air supply needed for their design.

During the last part of the activity (Worksheet 4) students prepare their letter, on an individual basis, addressing the main key-findings of their work.

Plenary

A whole class discussion takes place. Each group presents their results for discussion and reflection. The teacher orchestrates a discussion that focuses on the core concepts (e.g., maximizing the number of cars using the facility, safety) used in solving the problem, and provides guidelines for further improving the students' solutions.

Designing a Parking Lot

Work sheet 1

Some fans of the university football team arrived late to the game last Sunday, and there was not space to park their cars. It seems that there was not enough parking space for many fans who wanted to attend the first game of the championship.

"I really want many people to come to our games, and we have to think how we solve the parking problem. It seems that there is enough space next to the stadium, in an underground facility, currently not used by the university. We have to better think on how to solve this problem", Mr Paul, the person in charge for the university sports club said.

"To avoid congestion in subsequent games, the University technical services will design a parking facility in the underground space, next to the stadium, as to facilitate the presence of many as possible fans", Mr. Paul said.

Since the space available for parking is not that much, technical services have to think wisely, in order to provide the best possible solution for the parking facilities. They have to take into account many factors, including enough space for turning the cars, space between cars that they can leave anytime they want, etc. They also have to take into consideration fresh air supply, elevators for the people use the parking facility, and lighting.

Answer the following questions

a. Which problem did the fans of the university team face last Sunday?

……

……

……

……

b. Which factors do the technical services have to take into account in designing the parking lots? Try to list up to ***four*** factors.

……

……

……

……

……

……

……

c. Do you think fresh air supply is important in an underground parking facility? Please explain.

……

……

……

……

……

……

……

Designing a Parking Lot

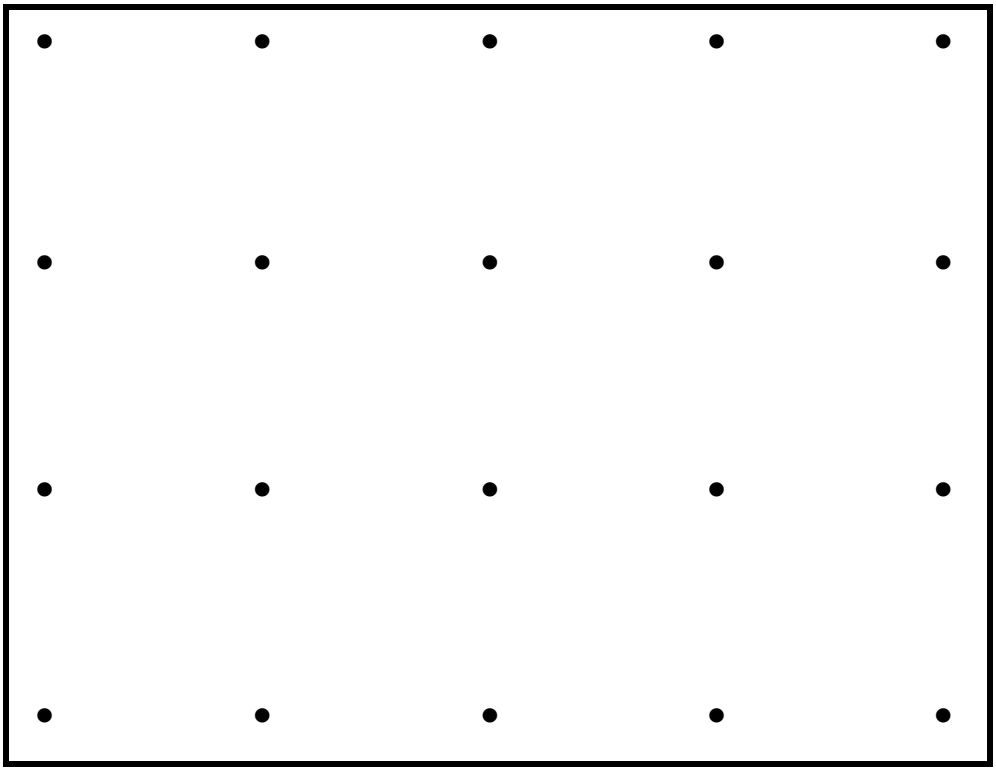
Work sheet 2

Task 1:

Below is the layout of the underground facility that is next to the university sports stadium. Each • represents a pillar!

Use the diagram to ***estimate the surface area of the parking*** (Note the scale!)

You can also import (or redraw) the diagram into GeoGebra and measure/ calculate the area using the software's tools.



Scale: 1:500

Task 2:

A possible good idea would be to think of the space allocated for parking the cars, and for the space used to drive the cars (lanes). Copy the parking space shape from above, and show the two parts.

In implementing your work, you could think that an average car's dimensions are 5 x 2.5 m.

Remark: It is not necessary to work in this way. A discussion with students might result in a different (even better!) approach. However, the teacher should facilitate students' work, especially at the beginning of solving the problem.

Task 3:

Complete the design you have carried out in Task 2, by identifying the space allocated for each car (think also of the space needed next to each car! People should be able to open/close car doors).

You might also want to think of other factors that might help you improve your solution (e.g., a pathway for pedestrians, moving from their car to the exit of the parking space).

How many cars can simultaneously use the parking space?

How could you increase the number of the cars, without decreasing the quality of your solution?

Task 4:

Assume that the parking space construction cost 100,000 euros, and the annual cost for maintenance and salaries is 3000. The university authorities would like to depreciate the cost in 5 years. How much should a ticket cost? (you should take into account some other hidden factors!)

Parking Facility Ventilation

Work sheet 3

In a garage or workshop where exhaust gases like Carbon Monoxide (CO) and Nitrogen Oxides (NO_x) from vehicles are very dangerous, proper ventilation of the area is very important. Garages can have natural ventilation with evacuation of air through ducts, although large garages should always have mechanical ventilation with fans.

Air supply

$Q = n*V$, where,

Q = total fresh air supply (m^3/h)

n = required air changes per hour (h^{-1}) – for an underground parking facility is at least 4 to 6

V = volume of the garage (m^3)

CO Emission

The fresh air requirement can also be calculated using the CO emission from the vehicles.

$q_{CO} = (20 + 0.1*D)*c$, where

q_{CO} = CO emission (m^3/h)

c = capacity of parked cars in the garage

D = mean driving distance for cars

The required fresh air supply can be estimated:

$Q = k*q_{CO}$, where

Q = required fresh air supply (m^3/h)

k = application coefficient [k = 2 where people are in the parking facility temporarily]

Example

The fresh air supply to a parking facility with *20 cars*, floor area *200 m^2*, volume *600 m^3* and a mean driving distance for the cars of *10 m*, can be calculated as:

Required air changes per hour: $Q = (4*1/h)\ (600\ m^3) = \underline{2400}\ m^3/h$

CO emission: $q_{CO} = (20 + 0.1*(10\ m))*(20\ cars) = 420\ m^3/h\ CO$

Required air flow due to CO emission: $Q = 2\ (420\ m^3/h) = \underline{840}\ m^3/h\ air$

Comparing the two calculations - the fresh air supply should be ***840*** m^3/h.

Task 1:

Calculate the fresh air supply for the underground parking facility you have designed. Show your work in the box provided below.

Designing a Parking Lot

Work sheet 4

Write a letter to the University Technical Services, explaining your design and how your team worked in solving this problem. In your letter you should make explicit how your team used your knowledge from physics, geometry, and algebra in solving the problem!

Dear Technical Services,

Our team, _____, proposes the following solution for the parking space problem the university faces: