Perspectives for Lifelong STEM Teaching

Career Guidance, Collaborative Practice and Competence Development

3C4Life

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Erasmus+

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Perspectives for Lifelong STEM Teaching – Career Guidance, Collaborative Practice and Competence Development

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The 3C4Life project consortium consists of 12 partners from 6 European countries.

- University of Education Freiburg, Germany (Project Coordinator)
- Utrecht University, The Netherlands
- University of Jaen, Spain
- University of Lisbon, Portugual
- Vilnius University, Lithaniua
- Hacettepe University, Türkiye
- Ministry of National Education, Türkiye
- Zentrum für Schulqualität und Lehrerbildung, a Landesoberbehörde of the Ministry of Culture, Youth and Sports, Germany
- VOHO Netwerken, The Netherlands
- National Ministry of Education, Science and Sport, Lithaniua
- Directorate-General for Education (DGE), Portugal
- Conselleria d' Educació, Investigació, Cultura i Esport, Spain

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Foreword

Dear Reader,

In today's rapidly changing world, Science, Technology, Engineering and Mathematics (STEM) fields are one of the critical elements that underpin our societies and the global economy. STEM education aims to prepare students for future success by providing individuals with strong foundations in problem-solving skills, critical thinking abilities, and innovation. However, it is becoming more and more complex for STEM teachers to stay up-to-date in these constantly evolving disciplines and provide the best education to students.

The Perspectives for Lifelong STEM Teaching - Career Guidance, Collaborative Practice and Competence Development (3C4Life) project is an initiative that aims to find solutions to these challenges faced by STEM teachers. This book aims to empower teachers and support an effective STEM education by providing them with lifelong learning perspectives in the areas of career guidance, collaborative practice and competence development.

In this introduction, we will discuss the main aims of the 3C4Life project, the strategies it adopted to achieve these aims, and the opportunities available for STEM teachers. We will also discuss the barriers to STEM education and ways to overcome these barriers, shedding light on the challenges that future STEM teachers may face.

We hope that this book, beyond being a guide for STEM teachers, will encourage building a community and working together to improve STEM education. Because STEM education is a force that shapes the future of not only individuals but the whole society.

This book aims to support you and other teachers in incorporating the perspectives outlined into your classroom practice. The book provides interesting classroom examples that aim to equip students to deal with controversial real-life situations and to make decisions in terms of socio-scientific issues using data obtained through inquiry-based research processes. We developed this book as part of the 3C4Life Project (Approaches for Lifelong STEM Education - Career Guidance, Collaborative Practice and Competence Development, 2021-2024, icse.eu/international-projects/3c4life), funded by the European Union and in collaboration with 12 universities and ministries of education from 6 European countries.

We believe that this book will provide you with useful, practical information, new classroom practice ideas and innovative teaching approaches and will inspire you for your invaluable work with today's students and tomorrow's responsible citizens.

Katja Maaß

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I. Introduction

Are you a pre-service or in-service STEM teacher? Are you looking for useful and inspiring impressions, ideas and information about career options, co-operation and exchange possibilities? Or do you want to improve your teaching and classroom management competences?

3C4Life is an Erasmus+ project that offers attractive career information for STEM teachers, aims at enabling communication, exchange and co-operation between teachers in Europe and has created a platform where you can be inspired for your teaching. You can access all the content within the 3C4Life project on the teach4life platform. This section briefly describes the dimensions of the platform.

Career Guidance

The careers of STEM teachers can diversify in many different areas. They can take on different positions within the school or take on tasks outside the school that are relevant to STEM education. The various career profiles provide inspiration and information about different career paths and new career opportunities for STEM teachers. The career profiles show professional possibilities in three areas:

- Schools
- Higher education institutions
- Educational authorities

Career profiles provide information about the areas of responsibility, the competences needed and the formal requirements. Short career videos give an insight into examples of good practice. The educators in the videos talk about their career development and why they decided to follow a career path different from “classical” teaching in the classroom.

Collaborative Practice

An important aspect of the work of today’s STEM teachers is collaboration and exchange of ideas. teach4life Collaboration and Exchange Platform creates professional learning communities. In this way, it gives pre-service and in-service STEM teachers the opportunity to share their experiences and reach out to colleagues both in their home countries and in Europe. Pre-service teachers can learn from experienced in-service teachers. In-service teachers can work as ambassadors of STEM education and share their knowledge on how to deal with challenges in STEM teaching.

Competence Development

A stereotype about teachers is that they prepare a flow of lessons for themselves at the beginning of their career and then do not change them for decades. Such an approach is both monotonous for the teacher and does not produce the best possible teaching quality. Constantly engaging with new teaching approaches, such as inquiry-based learning, authentic contexts or interdisciplinary questions, gives a new impetus to the working life of teachers and continuously develops one’s self. This book contains a large archive of activities following these pedagogical approaches, categorised by subject and methodology.

In Chapter 2, the competences section includes 18 examples of (i) inquiry-based learning, (ii) authentic contexts, (iii) socio-scientific issues and in Chapter 3 the 3C4life classroom materials. For more information, PD materials and whole class activities, please visit teach4life.eu.

II.Competence Development

The dynamism of STEM fields drives teachers to continuously acquire new skills and strengthen their existing competences. The project “Perspectives for Lifelong STEM Teaching - Career Guidance, Collaborative Practice and Competence Development (3C4Life)” focuses on competence development as a critical element for STEM teachers to succeed in this ever-changing environment.

Competence includes not only an individual’s level of knowledge and skills, but also how they are able to use these knowledge and skills effectively. For STEM teachers, these competencies are not limited to having interdisciplinary knowledge, but should also include skills such as applying student-centred teaching strategies, integrating technology, and working collaboratively.

In this section, the 3C4Life project will examine the pedagogical approaches taken within the scope of competence development. It will shed light on the challenges that STEM teachers may face in the process of competence development and guide them in overcoming these challenges. It should not be forgotten that as STEM teachers continuously strengthen their competences, their capacity to provide a more equipped and inspiring education to their students will also increase.

These are;
- Inquiry Based Learning
- Authentic Contexts
- Socio-Scientific Issues

These approaches are under different disciplines within STEM education. For this reason, these activities are given under 4 sub-headings as “Science, Technology, Engineering, Mathematics”.

Inquiry Based Learning

Inquiry-based learning (IBL) is a learning approach in STEM education in which students are encouraged to be curious and actively participate in asking questions, problem solving and discovery processes. This approach supports students to ask their own questions, experience and gain knowledge through these experiences instead of receiving information passively. Inquiry-based learning provides students with the opportunity to be more active and independent in the learning process, allowing them to develop critical thinking, problem solving and analytical skills.

In inquiry-based learning, students take an active role and investigate a topic in a similar way to researchers: They find and identify problems, develop ideas on how to investigate these problems, formulate hypotheses, test them, discuss the results, etc. In this way, in addition to the actual subject content, students practice dealing with new questions on their own. The teacher’s task is to create learning environments in which this is possible and to cultivate a culture of curiosity, constructive handling of mistakes and good communication with the students.

Usually students carry out an IBL task as follows (Inquiry Cycle)

- Create a specific question (Ask)
- Use available information to understand the problem and investigate possible solutions (Research)
- Create new findings based on previous findings (Create)
- Discuss the findings (Discuss)
- Evaluate the result and improve the solution if necessary (Reflect)

Authentic Context

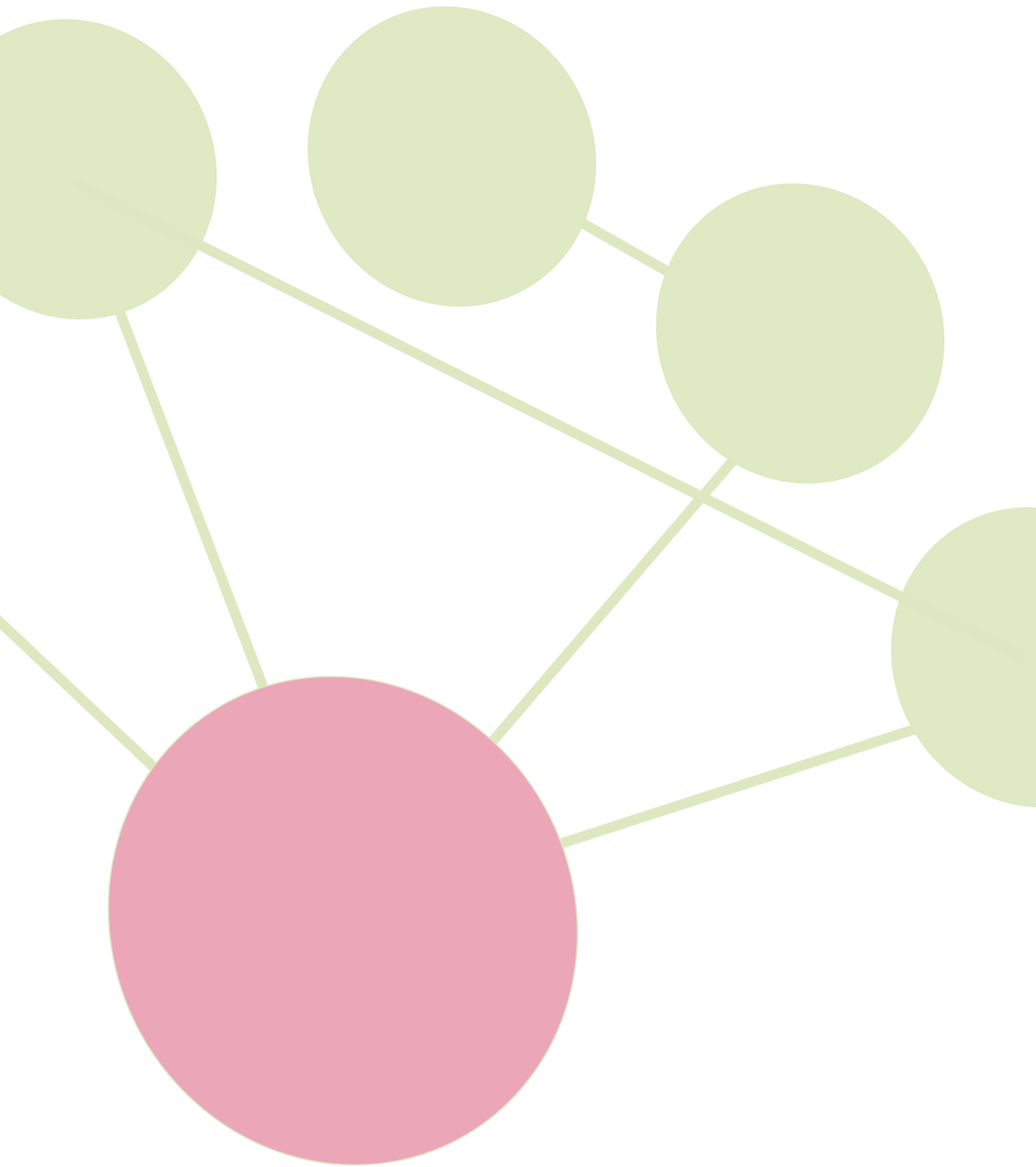
The concept of “authentic context” in STEM education refers to an approach in which learning experiences in mathematics, science, engineering and technology are based on real-world applications and students learn in a concrete and meaningful context. This allows students to learn abstract concepts and knowledge not only in the classroom, but also by relating them to their daily lives or real-world problems.

Authentic contexts (AC) are tasks that contain authentic references to reality; these can be situations from everyday life, professional life or social interest. Realistic portrayal of reality plays a particularly important role in such tasks. Contexts from everyday life, science, the professional world or society can be very motivating. On the one hand, authentic contexts touch the students’ world because students can have personal experiences with the topic. On the other hand, the teaching content can be directly linked to everyday life and thus remain in the memory longer.

Socio-Scientific Issues

Socio-scientific topics (SSI) in STEM education are topics that address the interaction and social dimensions of science and technology with society. These topics go beyond just technical skills and provide students with the opportunity to understand the ethical, social, cultural and economic factors surrounding science and technology. Socio-scientific topics place STEM education in a broader context and give students the possibility not only to acquire knowledge but also to understand how to use this knowledge in a societal context.

With ongoing societal issues such as climate change or the current Covid pandemic, topics related to maths and science have increasingly become a focal point in public debate. STEM teachers should provide learning experiences in the classroom that engage with topics related to these societal issues in order to prepare our students to actively participate in society. Socio-Scientific Issues are real societal issues that involve available scientific data, which can also be controversial. Because of the controversial nature of the issues, engaging with SSI requires both an understanding of the relevant scientific ideas and a careful consideration of the social, economic, political and ethical aspects of the issue.



III. Classroom Materials

Within the scope of the 3C4Life project, 18 different activities were developed by the consortium to support the professional development of teachers working in STEM fields, to provide best practices and to guide teachers with activities that can be used directly in the classroom. The focus of these activities is secondary education level (11-15 years old). Each activity is categorised according to the basic principles of the 3C4Life project as pedagogical approach used.

Each example provides a general and summarising overview of the content and implementation possibilities of the classroom activity. You can access the activities in this book and more on our teach4life.eu platform.

Please feel free to use these examples in your own lessons or in teacher training activities. If you have any comments and observations, please contact us to share them.

Below you can find and easily access the pages of the activities, which are divided according to the three pedagogical approaches.

Inquiry Based Learning Activities 18
- Love is all around 20
- Designing a 3D-printable Toothpaste-Squeezer 22
- Animal Footprints 24

Authentic Context Activities 26
- How Bio are Bioplastics? 28
- What is a good password? 32
- How to build a pontoon bridge to evacuate civilians? 36

Socio-Scientific Issues Activities 40
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Inquiry Based Learning


src:pixabay

Love is all around

STEM
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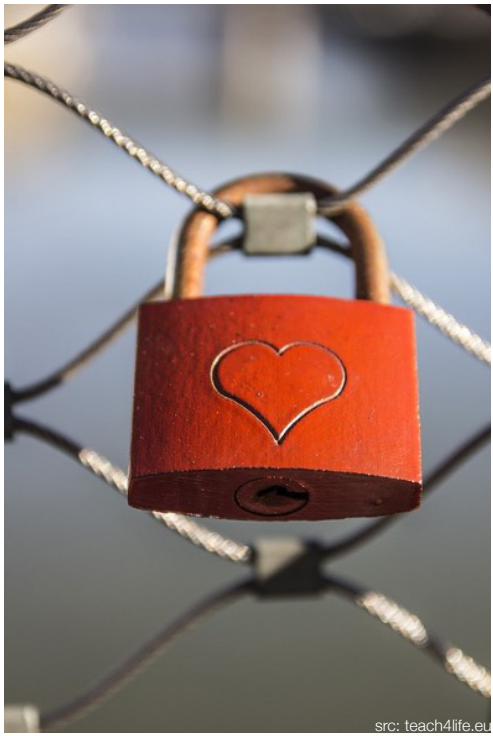
University of Education Freiburg
Germany

Attaching padlocks, especially to bridge railings, has been a popular trend among newly in love couples for years as a symbol of their love. However, in several cities padlocks have already been removed because they block the passage and the total weight of the locks should endanger the safety of the bridge?

Do you share the safety concerns if a bridge is hung with love locks?



Details

Is there anything more romantic than professions of eternal love to your partner? If you look closely, they can be found in almost every city: countless bridge railings are hung with so-called „Love locks“. Some of these locks are engraved, some colorfully painted with the lover’s names, again other’s origins remain secret . But there is one thing they all have in common: They symbolize the attachment and devotion of the people who put them there. But what happens, when there are too many love locks on a bridge? Or when the bridge has to be renovated? Last year quite a few locks had to be removed from the railway bridge in Cologne due to the fact that they were partially blocking the bikeway. In some cities the locks had to be removed just as a result of the sheer weight they add to the bridge.

But exactly how much additional weight does a bridge actually have to carry if it’s hung with love locks? And how long would it take to remove all of the locks? Begin by considering how many love locks could approximately be hanging on a well-known bridge (like the railway bridge in Cologne). Inform yourself about how much money you could get by giving away the iron from the padlocks. What charity do you think a city should donate the money to?

Implementations

As long as simple physical concepts such as weight have been introduced, this task can be used at almost any age level. However, a basic understanding of geometry helps to create comparatively accurate solutions.

Solution

There is obviously not an exact solution to this problem. First we start with a question: How much is the overall weight of all the padlocks on the bridge?

The solution depends on physical factors as

- The length of the bridge
- The height of the railings
- The type of the railings (see the different pictures below)
- The average weight of a padlock
- The average size of a padlocks
- The density of the padlock distribution

Possible Solution

We have to start with some assumptions:

- Lenght of the Bridge: 60m,
- Height of the railling 1m
- Seize of a Lock: 2cm x 4c,
- Weight of a padlock: 0,1kg (via internet research)

Under these assumptions, we get

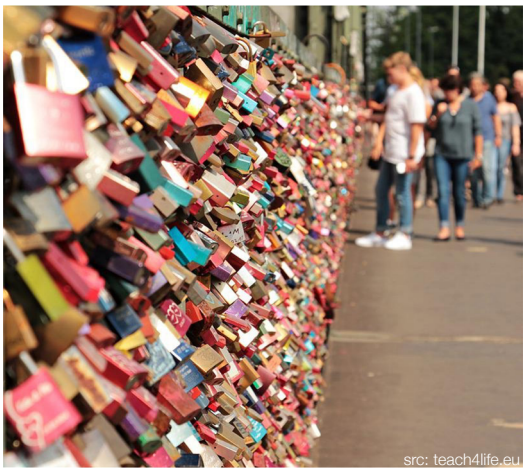
- Number of locks that will be used per m^2=1/(0,02*0,04)=1,250
- Overall weight of the padlocks: 1,250*60*0.1kg=7500kg

This is the weight of approximately 100 Persons which should not be a problem for a bridge. However, this result can be refined in various ways.

IBL in this Example

The Question of the padlocks overall weight depends on several uncertainfactors, i.e. avarage weight of the padlocks, geometry of the bridge (lenght, type of railings, density of the padlocs etc).

Students must make certain assumptions and use them to design a mathematical model that describes the ultimate load of the bridge. The model is then validated and revised if necessary.


src: teach4life.eu

Designing a 3D printable Toothpaste-Squeezer

STEM
Oliver Straser
University of Education Freiburg
Germany

We all know the problem. When a tube of toothpaste runs low, we have to use a lot of strength and skill to get at the toothpaste at all. And no matter what we do, we get almost nothing or far too much out.

Can you develop a tool so that it is no longer so difficult to squeeze the remains out of a toothpaste tube?

src: teach4life.eu

Details

Can you develop a tool so that it is no longer so difficult to squeeze the remains out of a toothpaste tube?

1. To do this, take a toothpaste tube that is already comparatively empty and try to empty it further. How do you go about it?
2. Now think about a tool that would make it easier, design it in 3D and print it.
3. Does your design work? Could you improve it? Keep going until you are satisfied.
4. For the quick ones: Could you make money with your design? Calculate your production costs and think about how much money you could get for your product. Would it be worth it to produce your toothpaste squeezer with the 3D printer?

Implementation

This task can be carried out in early STEM lessons (from grade 7, depending on the curriculum). In addition, only very basic computer-aided design (CAD) and 3D printing skills are required to create working toothpaste squeezers.

For example, Tinkercad (**https://www.tinkercad.com/**)is a free, comparatively simple 3D design software with a class management system for teachers and tutorials for students, which is absolutely sufficient for this project.

A possible integration in a STEM education depends on the equippement, but could look like

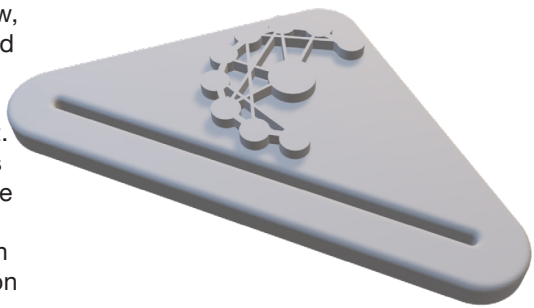
1. Confront the students with the toothpaste problem. Different (almost) empty toothpaste tube are helpful for this task.
2. Formulate the goal (Design and print a toothpaste squeezer)
3. If necessary: Give a short introduction to 3D-Design (or let the students work themselves through tutorials) and 3D-printing.
4. Students work through the exercise sheet till the first prototypes will be printed. We all know the problem. When a tube of toothpaste runs low, we have to use a lot of strength and skill to get at the toothpaste at all. And no matter what we do, we get almost nothing or far too much out. Can you develop a tool so that it is no longer so difficult to squeeze the remains out of a toothpaste tube?
5. After the first prototypes have been printed, the testing and optimization phase begins. The students test their products, describe what works well and what doesn't work so well, and then optimize until they are satisfied. The research cycle should also be addressed in this context.

Solution

There are very many well working solutions for this problem. Most are based on squeezing the toothpaste tube evenly across the entire width. You can see one possible solution here. Usually, a few iterations are necessary to get an optimally working squeezer. Factors which can be improved include

1. Width and height of the slit
2. Rounded edges in the slit
3. Thickness of the squeezer
4. Overall geometry

Whether the product is profitable depends on many factors. The production costs per squeezer are a few cents (approx. 0.3€ including material and energy costs) depending on the chosen print material (most likely PLA) and can be reduced with an cost-optimized design. In addition, there are costs for maintenance, wear and tear, and personnel. Additionally, the demand is probably limited so it would probably be suitable for a small side business, at best.



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IBL in this Example

In this task, students develop a product that is a solution to a real-world problem (toothpaste tube pushers are offered for sale on the Internet). Depending on the age, the task will be more or less open-ended. Students analyze and describe the problem, develop a solution themselves, and design according to their own specifications (appearance, functionality, handling, etc.). Later, the prototype is tested and usually optimized several times (research cycle).

Animal Footprints

STEM
Subject: Biology

Ragnhild Lyngved Staberg,
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Norwegian University of
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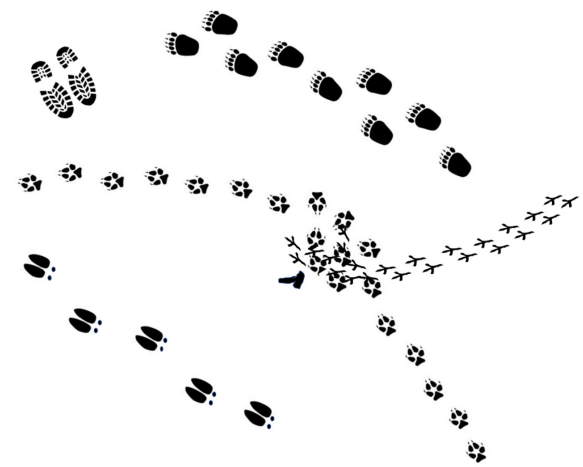
Norway

Probably you have all seen them in the sand, soil or snow; animal footprints! But what can they tell us?

Have a look at the drawing below. Based on what you know about animals, footprints, food chains, competition and ecological relationships; what do you observe?



src: teach4life.eu

Details

Have a look at the drawing. Based on what you know about animals, footprints, food chains, competition and ecological relationships; what do you observe?

Can you suggest 'a story' behind these footprints? What happened here? How many animals were here? What were they doing? What kinds of animals were they? Were they all here at the same time?

Do some research on footprints. From which countries or parts of the world could this story come from? Can you make your own story and drawing, based on animals in your country? Let other students explain your story.

Implementation

This task can be implemented in Biology and natural sciences classes from grade 3 on. It lays the foundation for understanding connections in the environment and knowledge about different animal species, tracks, food chains, and natural competition.

As teachers, we play a particularly important supporting role in this task because we need to encourage students to think independently, to formulate questions on their own, and to find their own answers to these questions. We should encourage students to think and argue out loud. We should also ask questions carefully and have examples ready in case they get stuck. We support the students in thinking at a higher level than before.

Solution

The aim of this task is to strengthen the students' observation, interpretation and reasoning skills. The students are asked to formulate conjectures about what the traces are all about. The task supports inquiry-based learning because it addresses aspects such as explaining, evaluating, and communicating findings. Students should be given ample time to consider the task and present arguments for their conjectures.

Depending on the age and maturity of the students, they are likely to suggest different explanations, as for example food search, starving, fighting or mating.

IBL in this Example

This task encourages both creativity and the ability to interpret what is observed. The goal is to connect to students' environmental knowledge and make sense of the food chain. The task has not only one correct solution, but quite different ones. The students' ideas and assumptions provide a good starting point for argumentation and discussion.

src: teach4life.eu

Authentic Context

src: teach4life.eu

How Bio are Bioplastics?

STEM
Subject: Chemistry

Oliver Straser
University of Education Freiburg
Germany

Bioplastics as PLA (Polylactide) have become very popular in the packaging industry. For example, PLA is often used as a material for yogurt cups and is the most widely used material in the private 3D printing sector.
They are considered to be resource-efficient to produce and compostable. But does that really make them better for the environment?

Details

The pollution of the sea by plastic waste is one of the unfortunately many big ecological problems of our time. Every year, 10 million tons of garbage are dumped into the sea, 75% of which is plastic waste that hardly decomposes and poses a serious problem for the marine ecology, especially fish, birds and turtles mistake the plastic waste for food and die from the consequences.

For example, a plastic bag takes about 10 to 15 years to decompose in the ocean, and a PET bottle takes up to 500 years to decompose. On the other hand, the food industry tries to increase the shelf life of food by clever packaging, thus reducing food waste as much as possible. Therefore, alternatives to classic plastic packaging are being searched for.

Bioplastics as PLA (Polylactide) have been become very popular in the (packaging) industry recently. For example, PLA is often used as a material for yogurt cups and is the most widely used material in the private 3D printing sector. Ordinary plastics require petroleum to manufacture and are not compostable. PLA belongs to the so-called bio-based biodegradable plastics, i.e. PLA is produced from renewable resources and can be decomposed by microorganisms using enzymes under certain conditions. But doesn't this sound a little bit too good?

1. Follow the synthesis instructions to produce PLA yourself. Is it really based on renewable sources? **https://www.lehrplanplus.bayern.de/sixcms/media.php/72/IA_C_13_LB3_Polymilchs%C3%A4ure.pdf**
2. *Optional:* Take your synthesized PLA sample to plan and conduct an experiment to figure out if PLA is compostable.
3. Do your own research and discuss the advantages and disadvantages of using bioplastics. (Is it really favourable to have bio-based plastics that will be composted afterwards?)

Implementation

The reduction of (plastic) waste and the overall protection of the environment has been a prominent youth issue, at least since the Fridays for Future movement. Bioplastics are often used in an attempt to improve the eco-balance of a product. As the task shows, from an ecological point of view the use of PLA can only be advocated if an ecologically sensible recycling of the materials is subsequently guaranteed. For this reason, many companies, from start-ups to corporations, are now focusing on the recycling of PLA and comparable plastics.In addition to the synthesis of PLA, the further processing, e.g. through mechanical or chemical recycling, can also be discussed in the context of the plastics lesson, and local companies that have specialized in the further processing of bioplastics can also be presented.

Solution

Advantages of of PLA:

- PLA (polylactide) is a polymer that (unlike classic plastics) is obtained from purely biological materials (e.g. corn starch) and without the addition of petroleum.
- PLA a degradable bio-based plastic.
- The CO2 balance during production is significantly better than that of comparable petroleum-based plastics (e.g. PET).

But:

- PLA is compostable, i.e. it decomposes into its (purely biological) components within several months only in industrial composting plants (58°+).
- In domestic compost, PLA decomposes only very slowly. The duration of composting is usually a few months (but longer than the normal composting time, so PLA is perceived as a nuisance material in composting plants)
- Most composting facilities are not capable of composting PLA.
- In the sea PLA hardly decomposes and increases the pollution by mircoplasts.

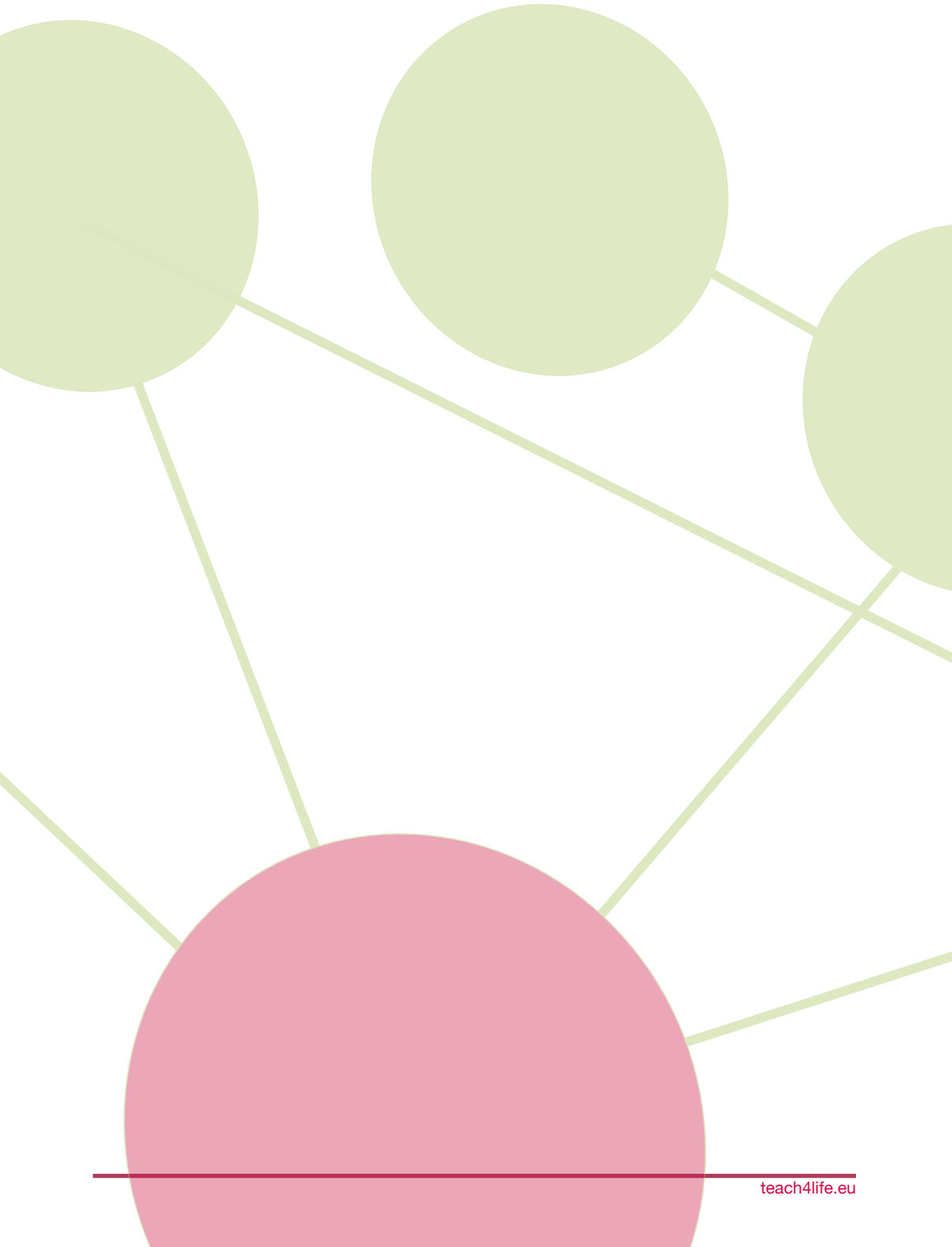
However, from a purely ecological point of view, composting is not the most efficient way to recycle PLA.:

- PLA can be effectively recycled with mechanical and chemical methods.
- Composting is not recommended from an energetical and environmental point of view.
- Sorting and cleaning is particularly costly, therefore PLA waste is often not recycled.

Sonuç: From an environmental point of view, PLA waste stored in a pure form is a big step forward compared to ordinary plastic waste. In all other cases it depends on local factors (for example: Are there sorting plants that seperate the plastic waste?)

AC in this Example

Are bioplastics an alternative to conventional plastics? The answer depends on many factors. As a purely ecological factor, mostly yes, at least if the country's technical infrastructure allows separating plastic waste by type and has the capacity to mechanically compost or recycle it. From an economic point of view the answer is mostly no, but this is likely to change if energy prices continue to rise rapidly.

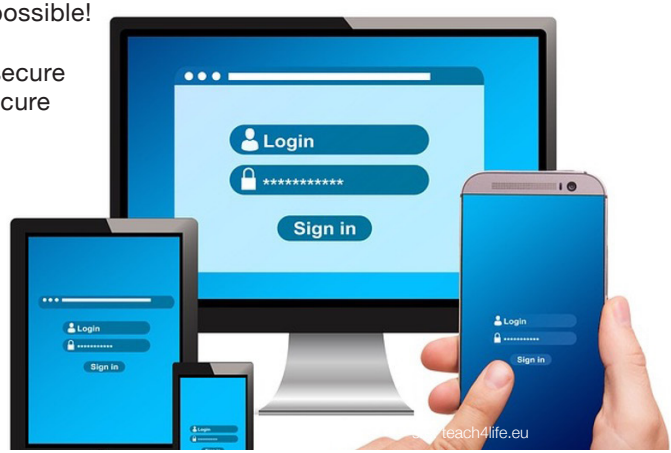


What is a good password?

Oliver Straser
University of Education Freiburg
Germany

If you want to write emails, post something in a social network or simply order something online, you always have to log in with your own username and password. For every email account, every social network and every online store you need your own password, and it should be as secure as possible!

But why is it important to use secure passwords and what does a secure password actually look like?



Details

If you want to write emails, post something in a social network or simply order something online, you always have to log in with your own username and password. For every email account, every social network and every online store you need your own password, and it should be as secure as possible!

However, most people use the same password for every account and mostly a very simple one. According to a research from Nordpass (**https://nordpass.com/most-common-passwords-list/**), the ten most common passwords worldwide in the last year were:

- 123456
- 123456789
- 12345
- qwerty
- password
- 12345678
- 111111
- 123123
- 1234567890
- 1234567

1. Why is it so important to have a secure password and what could be the consequences for you if someone finds out your password, e.g. for social media, email or online shopping?

2. The most common passwords in your country are also listed in **https://nordpass.com/most-common-passwords-list/.**

a)What were the most 10 common passwords in your country?

b)Why did people use this passwords?

3. The strength of a password can also be checked online: **https://nordpass.com/secure-password/**

a)How long needs a computer to crack the ten passwords from 2 a)?

b)What is a good password? Use this online tool to find out and describe characteristics for creating a good password that fits for you and test your criteria!

Implementation

The topic cybersecurity can should be integrated in early secondary technology education. Since at least email communication and the use of social media starts in lower secondary education (average between twelve and thirteen years) task one connects the topic cybersecurity to the student's personal life and should illustrate consequences for careless password selection.

Task two and three intends to let the students develop the capability of choosing optimal passwords for their own use. It is important to integrate a reflection phase in task three where the own characteristics for a good password are tested. Students should create a password by their own critics, tests its strength and try to memorize it and after this phase optimizing their critics.

It is important that the teacher mentions that there is not a perfect password and the choice of a password depends on personal factors as mentioned above.

Afterwards additional security measures while using the web should be discussed: (using secure connections, don't visit fringe websites, see bkz. **https://nordpass.com/secure-password/** "other ways to protect yourself online")

Solution

To Point 1)

A cracked password can lead to identity theft on the Internet. This results in the following possible consequences.

The thieves can communicate in the name of the robbed person on social media or via email. This can result in damage to reputation (e.g. insulting people or other inappropriate posts) or even criminal acts (threats of violence, announcement of criminal acts).

In the area of Internet shopping, the thieves can order at the expense of the robbed persons and thus cause financial damage.

To Point 3)
Computers almost instantly crack all the passwords from point 2. Following criteria influence the security of a password:

- The length of the password
- Types of characters used (just numbers, letters, special characters)
- The way characters are composed

In general, it is hard to describe when a password is secure: To give an example, the password „11111111“ would be cracked instantly, while the password „ 11111111 11111111 11111111“ needs 83 quintillion years to be cracked.

Possible characteristics are:

- 12 Characters
- Use numbers, letters and special characters

The security of a password also depends also on personal factors as mental capabilities as retentiveness, the ability of using mnemonics but also on the level of security needed for a password.

AC in this example

Authentic Context. There is no clear answer what a good password is. A good password must be relativly secure and the user has to be able to memorize it.

Besides that students have to develop and test criteria for a good password that works for themselves.

How to build a (pneumatic) pontoon bridge to evacuate civilians?

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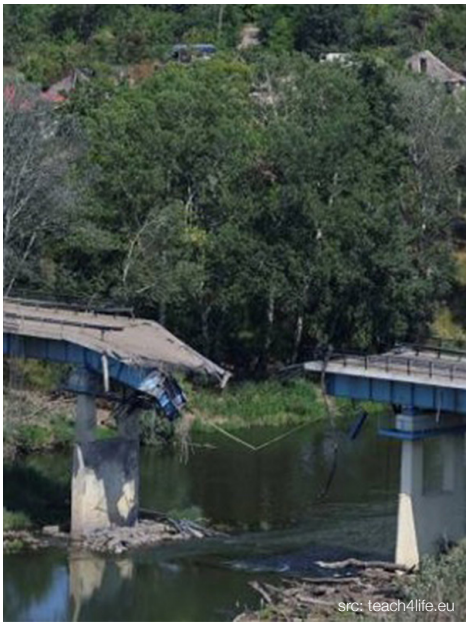
Engineering involves the purposeful application of mathematical and natural sciences and a body of engineering knowledge, technology and techniques to designing objects, processes, and systems to meet human needs and wants. Considering the recent warfare and natural diesters, it has been a issue to evacuate civilians since bridged were destroyed.

How can you build a (pneumatic) pontoon bridge to evacuate civilians?



Details

During wartime, natural disasters or civil emergencies, pontoon bridges have been considered as feasible solutions in terms of time, mobility, resources in hand or other factors. Considering the recent warfare, most bridges were destroyed. Thus, evacuating civilians was a serious problem. Drawing upon this issue, how can you build a (pneumatic) pontoon bridge to evacuate civilians and/or to deliver humanitarian aid? You may use Engineering Design Process among other design-based problem solving approaches to design a prototype of pontoon bridge.

Engineering Design Process is an analytic and creative problem-solving process that engages a person in opportunities to make something physical and/or digital that matters. Engineers often use the Engineering Design Process described below to solve problems.

The Engineering Design Process revolves around five stages: Ask, imagine, plan, create, and improve (see Table 1). This process is not linear, you will go back and forth between these stages while developing things, objects, systems, or processes that solve the problem. The goal here is to apply engineering design process as students iteratively work towards generating creative solutions to a challenging problem and work like an engineer. Engineers chose a problem or identify a need to work on. Then, they do research and find possible solutions. Next, they create the solution they chose and test their prototype. Based on the evaluation results of how people react about the prototype, they improve their design.

1. Search recent wartime news and define the problem in an engineering context.

2. Brainstorm ideas and possible solutions.

3. Draw a model or build a fast prototype which addresses the problem

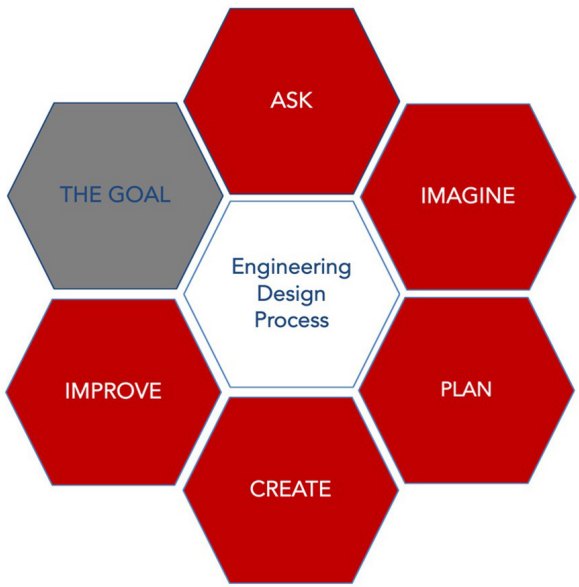
4. Make a list of materials needed and plan how to build the product

5. Follow the plan to create the product, tests the product, gather information/data from the testing

6. Evaluate the results, improve the design, retest and re-evaluate.

Implementation

Depending on the resources in hand a prototype of a pneumatic pontoon bridge can be build, tested, evaluated and refined. Recently, 3D printing technology has radically changed the prototyping process. The pneumatic pontoon bridge can also be produced by using a 3D printer.



Solution

When designing a pneumatic pontoon bridge, the engineer should take into account the Archimedes' principle stating that a body immersed in a fluid experiences an upthrust equal to the weight of the fluid displaced, and this is fundamental to the equilibrium of a body floating in still water.

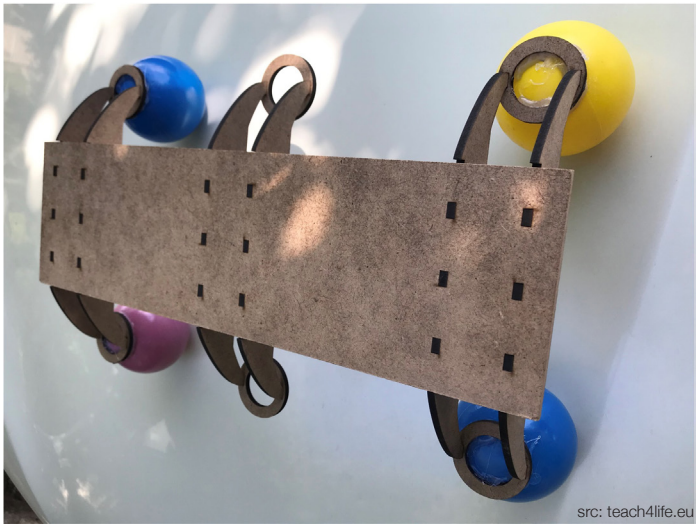
Further information about the solution also available at: https://www.sciencedirect.com/topics/engineering/archimedes-principle

More reading:
https://military-history.fandom.com/wiki/Pontoon_bridge

https://interestingengineering.com/the-pontoon-bridge-the-floating-bridge-from-ancient-china-used-in-the-biggest-20th-century-battles

AC in this Example

Engineering concepts and practices implicitly or explicitly integrated into K-12 curricula over the years. By doing so, design-based learning has been commonly used in addition to inquiry-based learning. In this example, the user experiences with an authentic real-life problem to develop a technology in this case a pneumatic pontoon bridge. Another good part of this example is that it includes both a design-based and inquiry based approaches for addressing the problem in hand.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Socio-Scientific Issues

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Should we expand our wind turbines?

STEM
Subject: Physics

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Wind turbines are generally considered a clean energy source. Nevertheless, the construction of wind turbines, especially near residential areas, divides society.

A wind turbine or simply wind wheel converts the kinetic energy of the wind into electrical energy and feeds it into a power grid. Today, wind turbines are by far the most important form of wind energy utilization.

In most areas, the potential of energy generation from wind turbines is not exploited. Should we therefore build more wind turbines, or not?


src: teach4life.eu

Details

The goal of this task is to show how different opinions evolve and strengthen.

1. Would you accept a wind power plant near your house? What are the advantages/disadvantages of installing wind power plants?

2. Put yourself in the role of a politician/expert. How would you argue…

a) … if you would like to promote the installation of a wind power plant close to your village?

b) … if you oppose installing wind power plants in your village?

3. Do your own research.

a) Find list of (seemingly) scientific based arguments favoring respectively opposing the use of wind power plants.

b) Elaborate on the connection between the main question and scientific facts.

c) What other aspects influence the decision on setting up wind power plants?

Implementation

There are many ways to integrate this into the classroom. In the simplest case, only the structure of the electric motor is discussed (topic induction), but there is also the possibility of analyzing the efficiency of the wind power plant, especially in relation to the geometry and number of rotor blades.

Solution

Advantages of wind power plants:

1. *Wind energy is a sustainable and clean energy source:* After construction, no resources are consumed for operation, no emissions are produces and modern wind turbines can be almost completely recycled at the end of their service life.

2. *Wind turbines have economic advantages:* The construction of wind turbines creates jobs and the operation of wind turbines provides communities with a sustainable income.

3. *Wind turbines are becoming more and more efficient*: thus they are considered one of the most important energy suppliers in the post-fossil ressources era.

Disadvantages:

1. *Reliability:* Wind is not constantly available and cannot be stored

2. *The construction of wind power plants is cost-intensive*: compared to fossil fuel power plants, such as coal-fired power plants, they are much more expensive to produce, but compared to other sustainable energy power plants, they are less expensive to build.

3. *Wind power plants have impact on human and nature*: Wind turbines are not silent, and rotors of wind turbines can pose a danger to animals (as birds, bats and insects).

4. *Wind power plants have impact on the landscape*: The landscape is also changed and shaped by wind turbines drastically, which impacts residents and tourists.

Of course, the arguments must be weighed against each other and the significance must also be put into context.

For example, although the damage to flora and fauna is immediately apparent, the long-term damage caused by coal-fired power plants, for example, must also be put into perspective here.

SSIs in this Example

Controversy in this example. Wind power plants are generally considered to be a clean energy source. However the installation of wind power plants also has impact on economical and biological factors.

Should self-driving cars have a moral conscience?

STEM
Subject: Biology

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Even though it is not yet permitted in many countries to drive cars completely autonomously, self-driving cars are becoming increasingly popular. Reports about fatal accidents with autonomous driving vehicles are always present in the media, but the car industry promises that in the near future autonomous driving systems will be in no way inferior to human drivers in terms of safety.

However, even if autonomous driving systems are safe, there may be situations where accidents are unavoidable. What rules should an autonomous driving car then follow?

src: teach4life.eu

Details

Autonomous driving plays an important role in many industrial sectors. From passenger transport to automated agriculture and transportation, many non-military application areas have opened up, which are intended to save personnel, costs and resources in particular. In almost all cases, video- and sensor-based systems are used to assess the current situation of the vehicle and thus influence its behaviour. For example, high-quality lawnmower robotor have camera systems that are capable of recognizing animals and children in the vicinity and intelligently avoiding them.

In the passenger sector, self-driving cars appear to be the next stage in the development of personal transportation. Even though it is not yet permitted in many countries to drive cars completely autonomously, self-driving cars are becoming increasingly popular. Reports about fatal accidents with autonomous driving vehicles are always present in the media, but the car industry promises that in the near future autonomous driving systems will be in no way inferior to human drivers in terms of safety.

However, even if autonomous driving systems are safe, there may be situations where accidents are unavoidable.

Use the following website to identify thirteen extreme situations where accidents are unavoidable: **https://www.moralmachine.net/**

1. Describe each situation in a few words.
2. How did you react in each situations and why?
3. Try to formalize situations where accidents may be unavoidable and the decision of the autonomous driving car results in an ethical conflict.
4. Do you think there is a perfect (i.e. objective) solution to this problem? If yes write an algorithm (in pseudocode) that solves this problem. (You can define functions as scenario I/II, number of fatalities, age, gender, misbehavior, social status: For example: if fatalities (scenario 1) < fatalities (scenario 2), then use scenario 1, else …)

Implementation

This topic can be embedded in a teaching unit on the topic of self-driving cars, e.g. by building an autonomous driving vehicle with the help of a mini-computer (e.g. Raspberry Pi).

With the help of an integrated camera, the situation can be simulated in a simplified way. Red and green spheres represent younger and older people, respectively. The vehicle has to drive through a parkour and find the best way from a moral point of view. The red and green balls can be identified with the help of **opencv.org.**

Solution

In all cases, there is material or human damage and even death. Simplified, it is assumed that there are always two outputs, in which there is always different loss. (e.g. older woman vs. younger child). The losses differ in number, age, social status and the behavior of the persons involved.

It can be assumed that a self-driving car evaluates the situation “objectively”, while people would at least rather protect their own life due to the instinct of self-preservation. For an “objective” evaluation of the situation, factors such as age, social status, gender, etc. must be weighted (if these can be recorded at all). I.e. subjective

definitions decide the outcome of the situation.

Put simply, each element of a scenario is assigned a value (loss of a female aged 32, for example, gives 100 points). The mathematical evaluation of the situation determines its outcome.

For example, a situation with i dead persons could be assigned the value

value(situation)= 1/(age_1)+...+1/(age_i)

to a situation with i dead persons. The instruction for the self-driving car would then be:

If
  Value(Situation 1)>Value(Situation 2)
then
  excecute (situation 1)
otherwise
  execute (situation 2)

Such an evaluation cannot be objective: First, because all factors can never be taken into account, and second, because the value of different human lives cannot be objectively compared. On the other hand, such an evaluation must also be made, because an autonomous vehicle cannot stop functioning in the middle.

There is a comparable situation in medicine when it is decided which patient is to be operated on first.

SSIs in this Example

Controversy in this example. The question breaks down on how much is a (human, animal etc) life worth. If a car has only two choices, hitting an elderly woman or hitting an infant the situation seems to be clear. But in depth analysis shows that in general it is required to measure the worth of a human life depending on factors like age, gender, behaviour etc.

The Case of Sally Clark

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In November 1999, Sally Clark, a respected lawyer, is charged with the murder of her children. Clark was suspected of murder after her two sons (*1996, *1997) died of sudden infant death syndrome within a short time after their birth. In the trial, the renowned pediatrician Professor Sir Roy Meadow was called in as an expert witness. He based his testimony on a statistical study which stated that the probability of a crib death in a family of the Clarks' social status was about 1 in 8543. From this, Meadow concludes that the probability of two such deaths occurring in the same family was equal to the square of that number:

1 in 73 million

Based on this statistical analysis, Sally Clark is found guilty of murdering her two children.

- What is the mathematical argument behind Meadows argumentation.
- Are the accusations justified? Do you agree with Dr. Meadow? Discuss this from a scientific and from an ethical viewpoint.

src: teach4life.eu

Details

In the United Kingdom, in September 1996, lawyer couple Steve and Sally Clark were overjoyed: on September 22, their son, Christopher, was born. Sally decided not to work for a few months and to stay at home with the child. Everything seemed normal until Dec. 13, when Sally went down to the kitchen to get herself something to drink. When she returned to the bedroom, she found the baby gray-faced in his bassinet.

She called an ambulance, which quickly took the child to the hospital, but unfortunately the little boy could not be saved. After Christopher's death, Sally resumed her professional activities, but while she properly pursued her work, she and her husband experienced a period of grief, depression and despair.

When the couple became pregnant again, the joy was great: on November 29, 1997, healthy little Harry was born. Like all younger siblings of infants who pass away in England, the baby was closely monitored. After the parents had put him down for a nap and checked on him again a little later, little Harry had turned pale. Steve rushed back into the bedroom, laid the child on the floor and tried to revive him. An ambulance drove the couple and the child to the hospital. But again, doctors were unable to save the child's life.

An autopsy was ordered, after which the pathologist believed there was sufficient evidence of maltreatment that warranted a full investigation. Sally Clark was arrested for the murder of her two children. Sally was tried at Chester Crown Court.

But then the distinguished pediatrician Sir Roy Meadow took the witness stand. Charming and jovial, Meadow was by all appearances full of sympathy for the defendant's suffering, took condemning words only hesitantly, which made his accusations more effective. He exuded competence, experience, skill, and kindness. As she listened to his testimony, Sally was paralyzed. "If I hadn't known I was innocent," she later said, "I would have been listening to him like that, I would have thought I was guilty." On the witness stand, Meadow felt it was important to share his knowledge, experience and conclusions to the judge and jury. Statistical research showed that ,,the likelihood of a crib death in a family of the Clarks' social status is about 1 in 8543," explained Meadow. "This means that the probability of two such deaths occurring in the same family is equal to the square of that number:

1 in 73 million"

On Nov. 9, 1999, by a vote of ten to two, Sally Clark was found guilty of murder and was sentenced to life in prison.

...and how did it turn out for Sally Clark?

In fact, doubts about the accuracy of the verdict arose immediately after it was handed down. Various scientists pointed out that the probability of dying of sudden infant death syndrome was of sudden infant death syndrome is significantly higher if a sibling has already died from it. Nevertheless, years passed before Sir Roy Meadows' opinion was officially challenged. It later turned out that a staphylococcus aureus infection caused both deaths. Sally Clark was acquitted in a second trial. However, she died a few years later as a result of heavy alcohol abuse.

Implementation

The goal is to understand how different opinions evolve and strengthen.
Read the text carefully!
What was the mathematical background of Sir Roy Meadow's argument?
Do you think Sally Clark is guilty and should be convicted? Argue!
Put yourself in the role of an expert.
How would you argue…

- if you think she should be convicted
- if you think she should not be convicted

Do your own (internet) research.

- Find list of (seemingly) scientific based arguments favoring respectively opposing the conviction of Sally Clark
- Elaborate on the connection between the verdict and scientific facts.
- What other aspects influence the perception of the case Sally Clark?

Solution

Meadow's argument based on the assumption, that the events A:={First child dies of sudden infant death syndrome} and B:={Second child dies of sudden infant death syndrome} are stochastically independent, i.e. he assumed that first equation and then he concluded the second equation

$$P(A \cap B) = P(A) \cdot P(B)$$

$$P(A \cap B) = 1/8543 \cdot 1/8543 \approx 1/(73\ Milyon)$$

However, the data situation for parents who loose two ore more children because of the sudden infant death syndrome is very thin and it is generally not known, if loosing a child because of the sudden infant death syndrome increases the probability for its siblings. This doesn't imply Clark was innocent, but it shows that Meadow's argument was evidently wrong. Some additional factors influenced the trail of Sally Clark.

- Professor Sir Roy Meadow is a well-known pediatrician, his title of nobility gave his argument an extra gravity.
- The case of Sally Clark got an immense media coverage. She generally was portrayed as the evil neglecting mother who murdered her kids, influencing the public opinion of her.
- She seemed to have personal issues. (Which also were amplified by the media coverage of her case)

Later it turned out, that the assumption of Dr. Meadow's argument is not true, and Clark was innocent. Her kids died because of a long-term consequence of a rare infection of the uterus.

SSIs in this Example

1. Argued by authory?

The gravity of the expert wittnesses testemony was undermined by his title of nobility. Criticisms of the ruling initially received little attention.

2. Conviction by probability?

The verdict based on a mainly statistical argumentation neglecting thepersonal circumstances and not, as it may look like, a trial based on circumstantial evidence.

3. Did sociological, psychological, political or media factors influence the case?

- Crime against children usually cause great stir.
- The media coverage of sally clark portrayed her as a murderer.

References

Some selected activities from the teach4life.eu platform are compiled in a book. HERE you can download the book in a PDF format. If you would like to reach more activities please visit www.teach4life.eu

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What is teach4life?

teach4life is an online platform for prospective STEM teachers and young as well as experienced practising STEM teachers. The aim of the platform is to increase the attractiveness of the STEM teaching profession in Europe by initiating dialogues between STEM teachers and connecting future and practicing STEM teachers.

We want to support you at all stages of your career and profession. Are you looking for new ideas for teaching? Would you like to exchange ideas with colleagues or are you interested in career opportunities in your profession? Then the teach4life platform is the right place for you. We offer you information about career opportunities, a digital network for STEM teachers and impulses for your teaching.

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