CIRCULAR ECONOMY AND TEXTILES

Teachers' handbook

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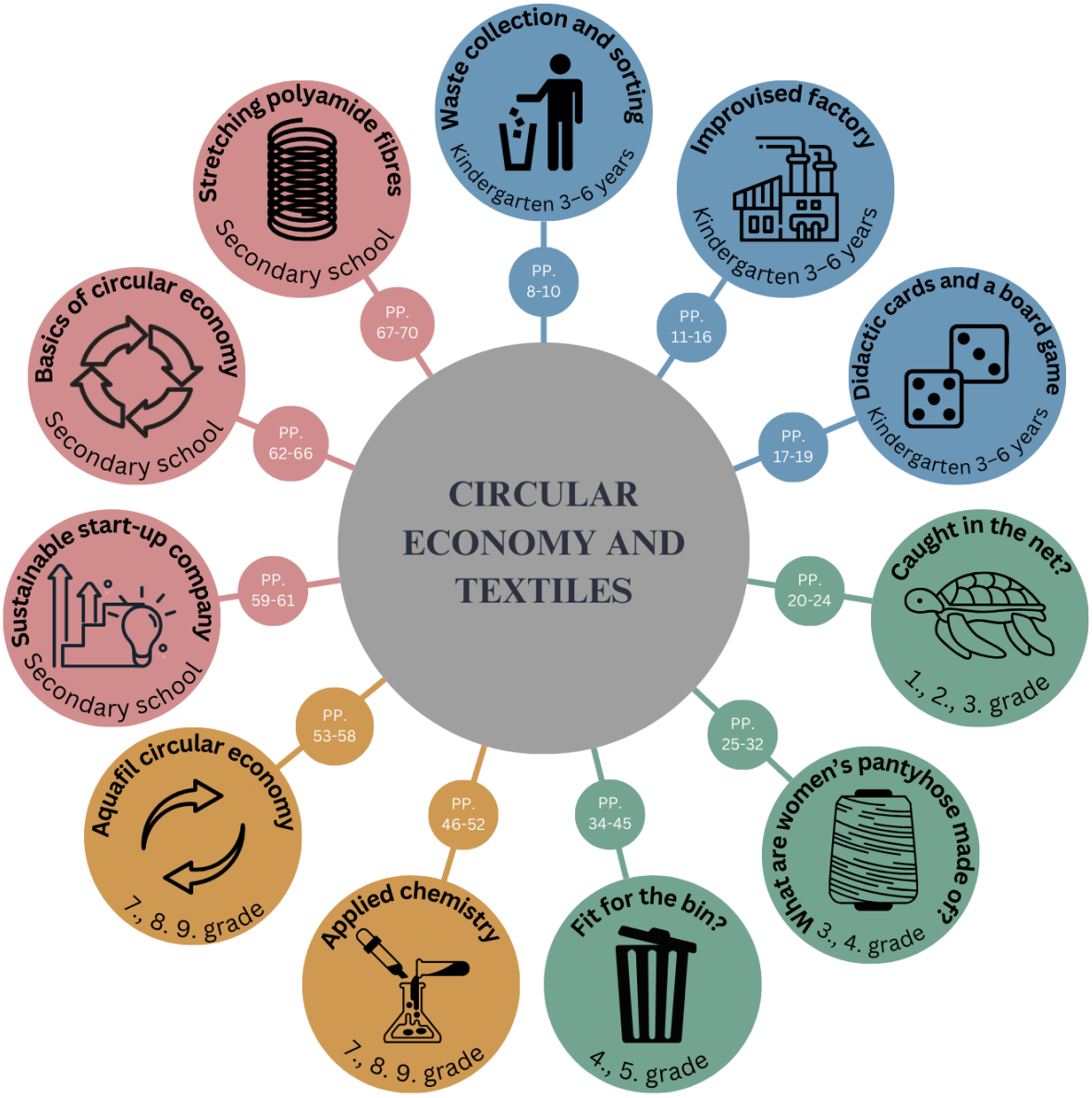

This **Circular Economy and Textiles** handbook includes eleven lesson plans for learning activities that aim to deepen the understanding and exploration of circular economy concepts. The activities are carefully tailored to the specific age groups and developmental needs of the students, whether they are in kindergarten, in lower or higher grades of elementary schools or in secondary school. It emphasises sustainable practices and responsible consumption, as well as sustainable and responsible living.

Introduction

Education on circular economy and sustainable consumption is important to raise awareness and promote sustainable practices in society. This includes providing knowledge, skills and understanding of how we can contribute to sustainable development and adopt circular economy principles in our daily lives.

Instead of only producing, consuming and throwing away products, the circular economy emphasises recycling, reusing and recovering resources. Materials and products are in a cycle, which reduces the consumption of goods, reduces waste and encourages reuse and recycling. It is important that children are introduced to the concept of circular economy during their primary education, as this helps to shape their attitudes towards sustainable practices, which can contribute to environmentally friendly decision-making and a sustainable society.

Circular economy education has to be experiential, with hands-on learning, so that people not only learn and teach, but also explore, question, seek, update, create and co-create. Such learning is underpinned by the educational principles of the Ekošola (Eco-Schools) programme, which launched its first dedicated education on circular economy in Slovenia in the 2016/2017 school year. The content and didactic material at that time was mainly related to packaging, e.g. paper, plastic bottles, milk cartons and juice cartons.

In 2019, the Eco-Schools Programme, together with the Foundation for Environmental Education (FEE International), developed a two-year pilot project Eco-Schools Advancing Circular Economy, with a strong focus on empowering mentors. A manual with lesson plans and worksheets was developed. Workshops and demonstrations of different practices were held to cover circular economy topics in upper primary school classes and in secondary school.

In 2022, AqufilSLO, as a pioneer in circular transformation in business, and the Eco-Schools programme entered into a partnership to set up the Circularity is our Opportunity project (Krožnost je naša priložnost), in order to encourage young generations to carry out activities that promote circular economy principles. Positive and feasible examples in practice, as well as new didactic materials, contribute to the project.

Within the *Developing didactic resources to teach the circular economy* project, students of the Faculty of Education – the first institution in Slovenia to obtain the Green Flag label of the Eco-Schools programme – and mentors from the Faculty of Education and the Faculty of Natural Sciences and Engineering in Ljubljana have developed the teaching materials, 11 lessons on circular economy that can be integrated and used in kindergarten activities, for teaching lower and higher grades in elementary school and in secondary school. The learning plans are designed with the aim of understanding and exploring the concepts of the circular economy. A variety of hands-on activities, videos, didactic games and discussions were recommended to teachers and students. Learning plans are tailored to each specific age group and to developmental needs of the students (kindergarten, lower and upper elementary school grades, secondary school) and they highlight the importance

of sustainable practices and responsible consumption. A wide range of topics is included, referring to waste separation, recycling, reuse, designing sustainable products, waste reduction and awareness raising as to the importance of circular economy. Each lesson plan includes a description of the learning objectives, an explanation of the new concepts, didactic activities and recommended reading material, making it easy for teachers to implement these activities in the educational process. Didactic activities enable students to develop critical thinking and problem-solving skills and encourage active participation and awareness of sustainable practices and their impact on the environment. Through this project, students and mentors from the Faculty of Education and Faculty of Science and Technology in Ljubljana have contributed to the development of useful didactic materials to promote the awareness of circular economy and build the foundations for a sustainable mindset and behaviour in future.

This handbook is a milestone in several ways, as education about circular economy through newly designed learning activities based on the example of textiles enters kindergartens and lower grades of elementary schools for the first time and offers new opportunities for higher grades of primary schools and for secondary schools. It will provide teacher trainers with competences for education in sustainable development. In addition, the manual brings together partners from different sectors, and we would like to highlight in particular that the teaching materials are the result of learning about circularity and the inspiration of our student authors.

We wish and we hope that the handbook will be a companion to many mentors. Above all, it should be an inspiration for networking and new ideas that will circulate among all of us. Conducting teaching activities, exchanging experience and implementing what we have learnt is what will truly bring us together in a circular society.

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Linear and circular economy

Circular economy is a way of organising activities – production and consumption – so that products, or the materials and substances in them, are kept in use for as long as possible. It is based on sharing, reusing, repairing, refurbishing and recycling existing materials and products for as long as possible. In other words, circularity is about keeping a product (the materials, substances in it) from ever reaching the end of its lifespan, so we keep it in circulation and use it in different ways. Circularity is inspired by nature, where all systems renew, rebuild themselves and grow without waste or excess materials.

What is the difference between linear and circular economy?

Modern production and consumption are based on linear economy and its pattern of take-make-use-dispose. In this pattern, a resource or material is used to produce a product or service, and after its use, the product is discarded. While this has brought about progress in a relatively short period of time, it has also made human activity and life entirely dependent on the use of natural resources, which are limited. Their overuse is evidenced by the so-called Earth Overshoot Day, also known as Ecological Debt Day. This is the day of the year when humanity's demand for natural resources exceeds its capacity to renew them. The consequences of this are both the scarcity of some natural resources and the excessive emissions of greenhouse gases and the resulting climate change.

In circular economy, one therefore thinks about extending the lifespan of a product from its conception (planning, design) stage onwards. In doing so, a path is set out that will allow it to be used for as long as possible, whatever the type of material and whatever the field of application, for example: plastics, paper, wood, textiles, electrical and electronic equipment, batteries, means of transport, food, energy supply, tourism, construction, and others.

Principles of circular design and action

The basic guidelines of circular economy are designing products and services without waste and pollution, keeping products and services in use and restoring natural systems. Decisions in the circular economy are made according to the nine principles: Refuse, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover (use for energy).

This is why in circular economy, the term circular design is often used, representing a holistic and systemic approach to the conception, planning, design, use and a longer life cycle of a product.

Impacts of circular economy

Circular economy is a way of achieving sustainable development. It influences the following:

- **Waste minimisation**: promoting the reuse, repair, sharing and recovery and therefore prevents waste;
- **Protection of the environment, natural resources and ecosystems**: slowing down the consumption of natural resources, reducing the encroachment on habitats and preventing biodiversity loss;
- **Reduction of greenhouse gas emissions**: reducing the impacts of industrial processes and product use;
- **Reduction of energy and resource consumption**: promoting the conception of efficient and sustainable products with the aim of reducing the environmental footprint over their entire life cycle;
- **Prioritisation of local production and processing**: giving priority to local resources and raw materials and other potentials, while taking into account their limitations and their capacity for regeneration;
- **Job creation**: circular conception and design requiring a systemic approach and the search for new options, products, services and operations;
- **Designing new systems and value chains**: circular systems and value chains are composed of a wide variety of actors that do not interact in a traditional, linear economy, whereas in circular economy they seek improved solutions through a collaborative and community-based approach.

Textiles, clothing and sustainability

The textile industry is one of the major polluters at global level. The main contributors to pollution are:

- **Water consumption**

During the production and processing of textile raw materials and in textile chemical processes, large quantities of water are consumed, leading to water scarcity in geographical areas where the industry is located and to the depletion of natural water resources.

- **Use of chemicals**

The textile industry uses a wide range of chemicals, including dyes, which are released into the environment during production, polluting the air, water and soil; they can cause health problems in humans and animals and a lasting damage to ecosystems.

- **Waste**

The textile industry produces large quantities of waste, including production residues, surplus materials and unused products. This waste disposal is often environmentally unfriendly, for example by landfilling or incineration, thus contributing to air, water and soil pollution. Over-consumption and fast fashion further increase the amount of waste.

- **Energy**

The production of textiles requires large amounts of energy in some processes, mainly to run machinery and to heat during the processes. Energy is mostly derived from fossil fuels, which increases greenhouse gas emissions and has an impact on climate change.

- **Transport**

Textiles and clothing are among the most global industry sectors. They involve long supply chains and intercontinental transport, so the use of fossil fuels further increases greenhouse gas emissions.

- **Microplastics**

The textile industry is also a major contributor to microplastic pollution in the oceans. Microplastics are small particles of plastic that come from a variety of sources and are a serious environmental problem. Washing synthetic clothes releases fibres that leach into wastewater and can end up in water systems, contributing to pollution. Microplastics can have harmful effects on aquatic organisms and entire ecosystems.

The textile industry needs to take responsibility for its impact on the environment and work towards more sustainable practices to ensure a sustainable future. Several strategies can be implemented to mitigate the environmental impact of the textile industry, including:

- **Using sustainable materials with a lower carbon footprint**, such as organic natural materials or recycled natural and man-made materials;

- **Implementing energy-efficient production processes** that can reduce energy consumption and greenhouse gas emissions, such as: incorporation of energy-efficient machinery and lean production techniques and renewable energy sources;

- **Implementing production processes to conserve water resources**, such as the use of recycled water, wastewater treatment, reducing water consumption and preventing water pollution;

- **Adopting the principles of circular economy**, i.e. encouraging the recycling and reuse of textiles to reduce waste. These principles are as follows: integrating sustainable concepts into the product development phase, digital innovation to optimise production processes and improve traceability in the textile industry, extending the lifespan of products by replacing fast-fashion products with quality products, popularising and implementing the repair, refurbishment and up-cycling of textile and clothing products, etc.;

- **Providing supply chain transparency, fair working environment and fair trade**, ensuring ethical practices, fair remuneration and safe working conditions; this strategy is supported by certifications such as Fairtrade and the Global Organic Textile Standard (GOTS), which help consumers to make informed choices;

- **Strengthening education, civic initiatives and awareness-raising** that encourage the collection and recycling of textiles and clothing, leading to a change in consumption habits and sustainable choices, and creating circularity;

- **Promoting local sourcing**, involving cooperation with local communities and support for local producers;

- **Systemic shifts** such as changes in policy, legislation and business models.

Sustainability in textiles and clothing has become a necessity given the strong environmental impact of the textile and clothing industry and the increased consumer demand for sustainable products.

Despite its many benefits, sustainability in textiles and clothing faces challenges as well. The textile and fashion industries involve complex global supply chains that make it difficult to track and ensure sustainability standards at all stages of the production process. Lack of transparency in the supply chain is one of the sustainability challenges. Fast

fashion, which encourages rapid changes in fashion trends and rapid production, also poses a major challenge. Recently, there has been a push for a shift towards slow and sustainable fashion, promoted by well-known brands. Sustainability in textiles also requires a change in consumer behaviour; changing consumption habits is a complex and lengthy process. In addition to the above, the high cost of sustainable materials and processes is a major barrier, as they often represent a higher cost compared to traditional materials and production. Especially for less established brands and designers, this is a reason why they fail to adopt sustainable approaches.

By adopting sustainable practices, the textile and clothing industry can contribute to a greener future, but the transition to true sustainability requires collaboration between all stakeholders in the industry, designers, retailers, consumers, policy makers and NGOs, as it is only by working together that the textile and clothing industry can be transformed into a more sustainable and environmentally responsible sector.

1. Collecting and sorting waste

EDUCATIONAL PERIOD: kindergarten 3–6 years

INTRODUCTION:

Waste is a major problem in today's world and there is no shortage of it. There are many ways in which we can reduce it and improve the situation in our neighbourhood and in the world.

The aim of this learning unit is to introduce children to recycling and to the operation of a factory that works according to the principles of circular economy.

NEW CONCEPTS:

Environmental pollution – it is the interference with the environment by various originally inexistent substances which have been created by humans as a result of the development of our civilisation.

Waste – it is the material that we produce, usually from technological processes and/or certain human activities. It exists in different aggregate state.

INTRODUCTORY MOTIVATION FOR STUDENTS:

Discussion about actual waste materials that can be collected together with the children in the kindergarten

- Which waste materials do we collect in the kindergarten?
- In which bin would you sort the following: plastic bottle, paper, newsprint, banana peel, bottle, glass jar, chocolate wrapper, etc.?

ACTIVITY IN CLASSROOM:

Learning objectives:

- The child learns about the problem of environmental pollution (water and soil).
- The child learns how a recycling factory works.
- The child develops fine motor skills of the hands.
- The child develops empathy for animals caught in fishing nets.

Duration: 60 minutes

Teaching aids:

Fishing nets and animals (turtles, fish, shells...), old carpets, village with houses

Course of activities:

Table 1: **Instructions for carrying out activities**

Title of the activity:	Role of the teacher:	Role of the child:
What waste materials are collected in the kindergarten?	Lead a discussion about what waste materials are collected in the kindergarten: Bottle caps Paper Clothes Plush toys What we do with the waste: We prevent waste. We separate it. Reuse it.	Listening and actively participating in the conversation
Waste separation	Bring waste bins (paper, packaging, glass, bio-waste, bin for textiles, bin for used batteries, bin for bottle caps, properly labelled) to the playroom. Also bring large amounts of different waste materials. These include a net and an old carpet. The conversation leads to the idea that there is a company that buys or stores waste fishing nets and carpets and uses them to make new products.	Naming the bins. Separating waste correctly. Listening and actively participating in the conversation.
Rescuing marine animals (turtles, fish, shells, etc.)	A large fishing net is brought into the playroom with various sea animals stuck in it.	Rescuing sea animals from the fishing net.
Discussing where waste fishing nets and carpets go	The teacher leads a discussion that these fishing nets are rescued from the sea by divers (who also rescue the marine animals) and the fishing nets are sent to AquafilSLO. The conversation leads to the fact that the company collects and stores waste fishing nets and carpets, recycles them and makes new products.	Listening and participating in the conversation.

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- *Kaj so odpadki*. (No date) *(What is waste.)* https://iamstudent.si/e-gradiva/gospodarjenje_z_odpadki/1_0_strokovna_terminologija_o_odpadkih/kaj_so_o dpadki.html
- *Onesnaževanje okolja.* (2023) *(Environmental pollution).* https://www.gov.si/podrocja/okolje-in-prostor/okolje/onesnazenje-okolja/

RECOMMENDED READING:

- https://ekosola.si/kroznost-je-nasa-priloznost-22-23/

2. Improvised factory

EDUCATIONAL PERIOD: kindergarten 3–6 years

INTRODUCTION:

The aim of this lesson plan is to learn about a factory that recycles waste materials according to the circular economy concept.

NEW CONCEPTS:

Circular economy is a process of reducing the impact of exploiting natural resources by focusing on the reuse, recycling and repair of products.

Fibre – it is a long, thin particle of matter, the basic constituent of textile products.

Parts of a factory.

INTRODUCTORY MOTIVATION FOR STUDENTS:

Different shapes, sizes of boxes to make a model of a factory.

Questions:

- What can we make from these boxes?
- The discussion leads to suggest that we can use them to improvise a factory that works according to the principle of the circular economy.

ACTIVITIES IN CLASSROOM:

Learning objectives:

- Children express themselves creatively while making a model of a factory.
- They learn about the parts of a factory and its main functions.
- They learn about the materials processed and extracted in the factory.

Duration: 100 minutes

Teaching aids:

Boxes, pictures of the factory and parts of the factory (Appendix 1), materials from each part of the factory – sensory box with materials (Appendix 2), crayons, wax crayons, markers.

Course of activities:

FACTORY MODEL:

Table 2: **Instructions for carrying out activities**

Title of the activity:	Role of the teacher:	Role of the child:
	The teacher brings a lot of different boxes to the playroom. They differ in size, shape...	They observe the boxes.
Constructing the factory model	The children arrange boxes of different sizes any way they want. The teacher instructs them to make a model of a factory out of the boxes.	Listen to instructions Put together a model of the factory.
Naming the factory	The teacher tells them that this is a factory that recycles waste materials.	Listen, participate in the conversation.
Naming factory parts and activities	- Cleaning waste materials - Grinding waste materials - Chemical recycling of materials - Manufacture of granulate - Manufacture of fibres - Winding the yarn onto a package For each process, the teacher shows the picture from the learning materials.	Participate in the activity and show initiative by taking part in naming the model factory. Observe and describe the pictures. Place the picture into the model of the factory.
	Include the pictures from Appendix 2 in each process.	Participate in conversation and learn about materials.
Free play in the factory	Observing the children participate in the discussion.	Play freely with the factory.

SENSORY BOX:

Table 3: **Instructions for carrying out activities**

Title of the activity:	Role of the teacher:	Role of the children:
Sensory box	Place the sensory box on the table in the corner of the model factory.	Explore, look, observe, compare materials in the box and in the improvised factory.

Appendix 1

Figure 1: Cards showing the processes in the factory

Appendix 2

Figure 2: Example of a factory model

Photographs that can be used in the discussion:

Figure 3: AquafilSLO factory

Figure 4: Collecting, cleaning and storing waste materials

Figure 5: Chemical recycling of waste materials

Figure 6: Manufacture of ECONYL® nylon granulates

Figure 7: ECONYL® regenerated nylon fibres on yarns on packages

Figure 8: Products

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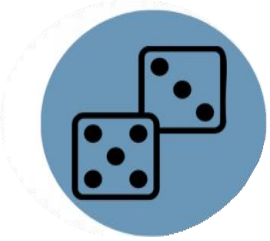
- Ekošola. (2022). *Krožnost je naša priložnost*. (*Circularity is our opportunity)* https://ekosola.si/wp-content/uploads/2019/11/Kro%C5%BEno-gospodarstvo_Ekokviz-S%C5%A0-19- 20.pdf
- *Kurikulum za vrtce: predšolska vzgoja v vrtcih.* (1999). Ljubljana: Ministrstvo za šolstvo in šport in Zavod Republike Slovenije za šolstvo.
- Slovarji Inštituta za slovenski jezik Frana Ramovša ZRC SAZU (Dictionaries of the Fran Ramovš Institute for the Slovene Language) https://fran.si/iskanje?Query=vlakno&View=1
- *AquafilSLO company website*. (No date) https://www.aquafil.com/slovenija/ and materials https://ekosola.si/wp-content/uploads/2022/09/Kro%C5%BEnost_OPIS-PRIMERA_Regenerirani-nylon-ECONYL.pdf

3. Didactic cards and a board game



EDUCATIONAL PERIOD: kindergarten 3–6 years

INTRODUCTION:

Factories are among the largest consumers of raw materials or natural resources extracted from the environment. Circular economy aims to reduce the exploitation of natural resources and to focus more on their reuse. It is important that individuals are aware of how they can contribute to this and to know, for example, what happens to the waste that is collected for reuse in factories.

The aim of the learning unit is to explain and demonstrate in a fun and playful way the processing of some waste in the context of circular economy.

NEW CONCEPTS:

Waste processing – the process of putting waste to beneficial use for a variety of purposes. The purpose of such processing is to recover materials that would otherwise be extracted from the natural environment.

INTRODUCTORY MOTIVATION FOR STUDENTS:

Show and introduce the cards from Appendix 1. Describe what is on them, then introduce the "Memory" game and the "Let's recycle everything" game and explain the instructions for the game (Appendix 2).

ACTIVITIES IN CLASSROOM:

Learning objectives:

- The children will learn about the processes of circular economy through playing the game and engaging in this activity.
- The children will learn and familiarise themselves with the content related to the processing of polyamide (nylon) by looking at the pictures on the cards.

Duration: 60–120 minutes

Teaching aids:

Cards, board game, polyamide (nylon) processing circle.

Course of activities:

Table 4: **Instructions for carrying out activities**

Title of the activity:	**Role of the teacher:**	**Role of the child:**
Getting to know the cards	Introduces all the cards and starts a conversation about what the children see/observe on the cards.	They look at the cards. Participate in the conversation about what they see/observe on the cards.
Playing with cards	1. Memory card game 2. Sorting cards by processing circle	1. Play with cards 2. Sort cards by processing circle
"Let's recycle everything" game	See appendix.	

REFERENCES:

- *Kurikulum za vrtce: predšolska vzgoja v vrtcih.* (1999). Ministrstvo za šolstvo in šport in Zavod Republike Slovenije za šolstvo.
- *Obdelava odpadkov.* (2023) https://spot.gov.si/sl/dejavnosti-in-poklici/dejavnosti/obdelava-odpadkov/

APPENDICES:

Appendix 1

Figure 9: Cards

Figure 10: Cards

Appendix 2: Game rules

Players place their game pieces at the start and determine who starts the game by rolling the dice. Whoever rolls the highest number of dots starts. The player rolls the dice and moves forward through the squares. When they reach a coloured square, they can take the card belonging to that particular square.

GREEN BOX – Fishing nets

YELLOW BOX – Granulate

RED BOX – Fibres on bobbins

BLUE BOX – Products (swimwear, interior textiles, e.g. for chairs or carpets)

OBJECTIVE: To collect as many cards as possible and thus process as many raw materials as possible.

The player with the most cards wins.

Appendix 3: Let's recycle everything game

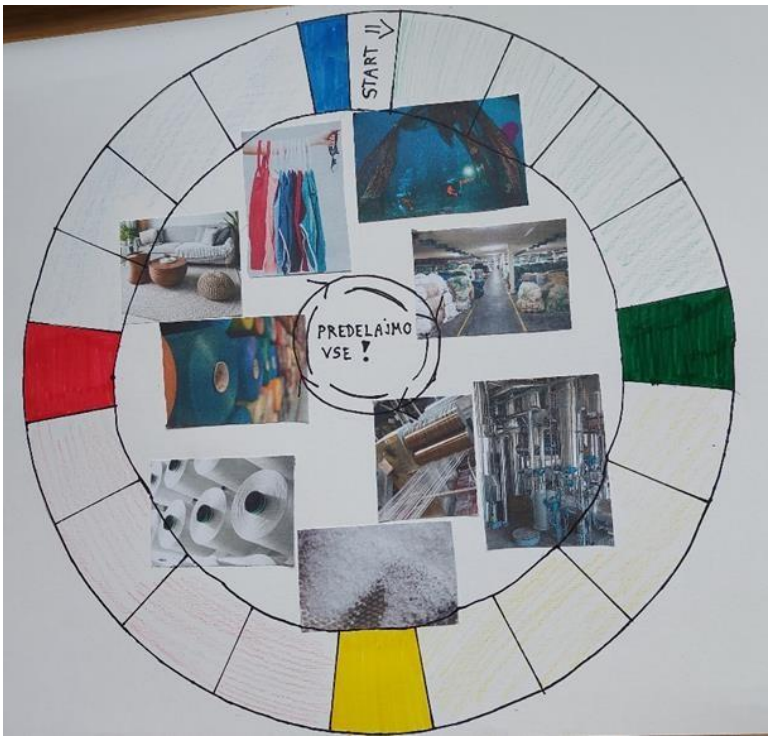
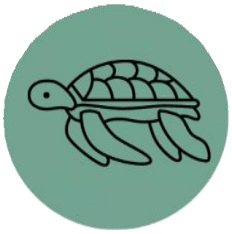


Figure 11: Example of a template for the Let's recycle everything game

4. Caught in a fishing net



EDUCATIONAL PERIOD: first educational period, 1st, 2nd or 3rd grade

INTRODUCTION:

Circular economy is based on the principle of reducing, reusing, recycling and recovering materials, and minimising waste, thus promoting sustainable and efficient management of resources. Several companies in Slovenia have already applied this concept. One of them is AquafilSLO, whose recovery process is presented to children in a short, simple and understandable way through the story of two turtles who discover the process of fishing net recovery.

AquafilSLO has been hailed as a pioneer of circular economy and is also the largest producer of polymers and man-made fibres in Slovenia. The ECONYL® regeneration system is based on four main concepts: rescue, regenerate, remake and reimagine. The first step (rescue) involves recovering nylon waste such as fishing nets, textile flooring and industrial waste containing polyamide (nylon) with the help of various organisations around the world. The second step – regeneration – converts the waste into raw material suitable for further processing. The brand new raw material (ECONYL® regenerated nylon) has exactly the same structural composition as the standard nylon coming from fossil resources. In the third step (remake), the ECONYL® raw material is converted into fibres, which are then used to manufacture new products in the fourth step (reimagine). ECONYL® fibres produced by Aqauafil are used in the fashion industry (clothing, swimwear, socks), in the textile flooring industry and in the automotive industry.

Recycling is a well-known form of reusing waste material. The most prominent example of this is the recycling of plastic packaging (plastic bottles, cartons etc.). An often overlooked fact is, for example, that cartons are the kind of packaging that is composite. It is therefore a good idea to learn what happens to them when they are recycled. It is disposed of in the yellow container for packaging waste. Recycling produces paper and a mixture of polyethylene and aluminium. This is used to make new products (paper and plastic). Alternatively, the whole composite packaging can be used to make new products, which is what we will try to demonstrate in this lesson.

NEW CONCEPTS:

Waste – substances or materials that are no longer useful or desirable and are discarded as useless, often causing environmental challenges.

Recycling – the process by which waste is treated and turned into new useful materials, energy or products.

INTRODUCTORY MOTIVATION FOR STUDENTS:

INTRODUCTORY ACTIVITY: Waste experiment (can also take place outside).

Teaching aids:

- Juice in a carton (one for each student)

At snack time, children are given a carton of juice to drink. The children gather in a circle and bring their empty cartons with them.

Instruct them to bring their own cartons from which they drank juice during snack. Lead a discussion:

1. What do we do with the carton?
2. What do you think happens to it when you put it in the container?
3. What do you think is the right thing to do with different types of waste? Why?

Keep the cartons for later because we will need them at the end of the lesson.

ACTIVITIES IN CLASSROOM:

Learning objectives:

- Students are able to use different materials, tools and processing methods and to relate the properties of materials with the way they are processed: reshaping, cutting, joining, gluing.
- Students know that some materials are used in factories and workshops to make useful products.
- Students know that production and everyday life generate waste that needs to be taken care of and that some waste can be reused.
- Students can describe appropriate waste management to protect and preserve the environment.
- Students become more aware of how important sustainable waste management is and they are encouraged to play an active role in protecting the environment.

Duration: 45 minutes

Teaching aids:

- Juices in cartons
- Scissors, glue, markers

Course of activities:

1st ACTIVITY: A story about circular economy

CAUGHT IN A FISHING NET

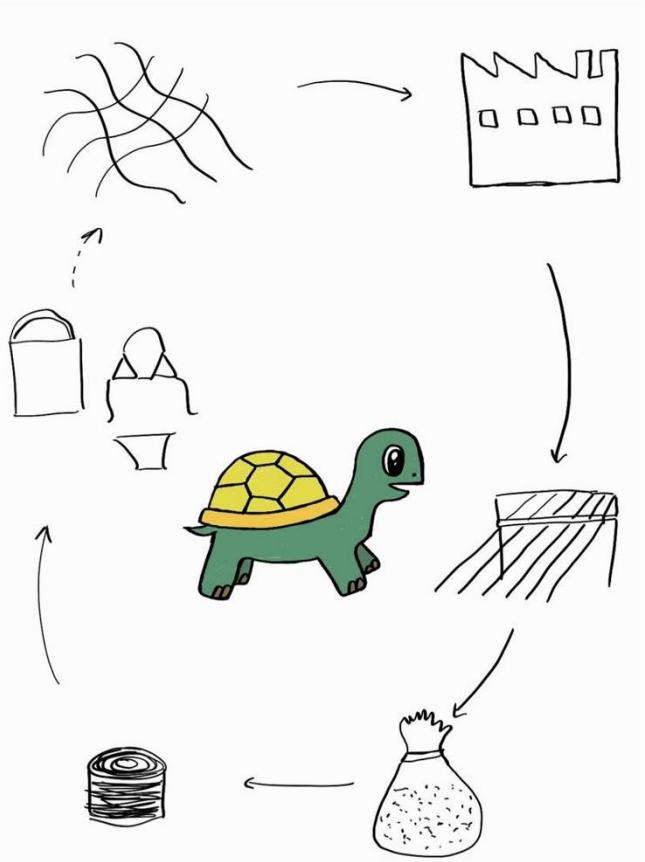


Figure 12: Illustration from the story

It was a beautiful sunny day. Two turtles, Pippa and Marco, were diving in the sea. They swam deeper and deeper. It was getting darker and darker. Suddenly Pippa felt that she got trapped somewhere. What could it be? She got entangled and could not swim to the surface. Marco the turtle noticed that his friend was no longer with him, so he swam back into the deep water to look for her. He found her trapped in a huge fishing net that people had left in the sea. He helped her slip out of the net and swim free again. "Oh, these people," thought Marco, "They never think about us animals living in the sea."

Shortly afterwards, they heard the hum of a motor and immediately knew that people were approaching. They were already used to this, as people often visited the sea where the two turtles lived. "What will they do this time?" they thought. They watched a diver jump from the boat into the water. He swam to the fishing net in which Pippa had been caught earlier and pulled it onto his boat. Pippa and Marco had never seen this before. They wondered where he was going to take the net. Curiosity got the better of them and they decided to follow the boat.

And so their adventure began. They swam to the boat and crawled on deck, where they watched people pulling big, dirty fishing nets out of the sea. When they had gathered enough, they started to sail towards the shore. They came ashore and carried the fishing nets, together with the two turtles, into a truck which drove up to a large gate. When it opened, a cloud of unpleasant smell engulfed them and they found themselves in a factory.

Pippa and Marco looked around and saw huge piles of fishing nets, scrap carpets and textile factory waste. They watched as the machines in the factory cut the fishing nets and other waste into tiny pieces. During the processing various machines then turned this waste into transparent thread. Pippa couldn't hide her amazement: "How is it possible that the dirty net I got caught in turned into such a beautiful and clean yarn?" Huge machines wound the yarn and the two turtles learned that the yarn was called nylon. Marco wondered what people use this yarn for and they set off to find the answer to the new riddle.

They found out that nylon is trucked to different factories and companies where it is made into swimwear, bags, backpacks and other products. The two turtles witnessed the whole journey from dirty fishing nets to beautiful swimsuits and had a great time doing it. They were happy to see that there are still good people out there who keep the environment clean and care for the animals in the sea.

When they returned to the sea, they saw children playing on the beach. They looked at their swimsuits and looked at each other with satisfaction, knowing that these swimsuits were made from nets that had been lying dirty at the bottom of the sea. They were happy that they went on this fun adventure and decided to tell the story to all their friends.

2nd ACTIVITY: things to do after having read the story

After you have read the story, there is a short break (30 seconds) to collect thoughts and feelings about it. Then ask the students: "Did you like the story? How did you feel during the story?" The students show their feelings by facial expressions (examples can be given in advance: joy = smile, sadness = sad face...). This is followed by a retelling of the story. The students can help themselves with the illustration provided (Fig. 12). Lead a discussion:

- Who was in the story?
- What did the two turtles find in the sea?
- Where did the people on the boat take the fishing net? What happened to it afterwards?
- What was made from the fishing net?
- How does the story end?

After the discussion, give the students blank sheets of paper for them to draw their chosen topic* (the first one is the easiest and the last one the hardest):

- Their favourite part of the story.
- What was happening to the fishing net during the story.

- What else could be made out of the fishing net.

*Students should be allowed to choose the task.

3rd ACTIVITY: Let's recycle the waste

Students make pencil cases/coin purses/small bags out of the cartons that had been used in the introductory activity (Appendix 1).

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APPENDICES:

Appendix 1

Figure 13: Example of recovering packaging waste

5. What are women's pantyhose made of?

EDUCATIONAL PERIOD: 1st and 2nd educational period, 3rd, 4th grades

INTRODUCTION:

Waste management includes waste disposal, collection, transport and treatment. Efficient waste management is essential for the development of human society as it contributes to the rational use of resources. Recycling has been already a well-established system in Slovenia, as it is among the better-ranked European countries in this field.

A prerequisite for developing circular economy is to think carefully and look closely at what a product is made of and what we do with it when using it. There are a few companies in Slovenia that make products from reclaimed or recycled materials and whose recycled products are fully comparable to new ones. An example of good practice is the company AquafilSLO that uses waste fishing nets, carpets and textile industrial waste as basic raw materials. These are first collected, cleaned and then regenerated to produce so-called recycled polyamide – ECONYL® nylon.

Its quality is identical to polyamide (nylon) made from crude oil, which is why the company is also a centre of research and development for circular economy.

The aim of this learning unit is to compare recycled and non-recycled products and to learn about circular economy.

NEW CONCEPTS:

Recycled products – products that were previously waste material but have been treated and processed into new useful products

Non-recycled products – products that have not been previously treated or processed from waste material and are not part of the recycling process

Nylon – name of man-made polyamide fibres used to make many products such as clothing, swimwear, textile floor coverings, etc.

Recycling – the process of treating and transforming raw materials or materials into new products or raw materials that can be reused

Circular economy – an economic concept based on the principle of reducing, reusing, recycling and recovering materials and minimising waste, thereby promoting sustainable and resource-efficient management

INTRODUCTORY MOTIVATION FOR STUDENTS: Recycled and non-recycled products – do you notice the difference?

Teaching aids:

1. different products/materials (toilet paper, paper sheets, towels, bottles, plastic bottles, etc.)
2. recycled products (recycled toilet paper, recycled bottles, recycled towels, etc.)

Students are told in advance to bring different products to school, such as paper, toilet paper, plastic bottles, bottles, towels, etc. The teacher brings different examples of recycled products for comparison.

We look at the products and judge whether they are recycled or not. If the students are not familiar with the concept of recycling, discuss this and introduce them to the recycling symbol. Next, the students sort the products according to whether they are recycled or not and put them in two separate places. Write the characteristics of recycled and non-recycled products on the board with the students.

Table 5: **Non-recycled and recycled products**

NON-RECYCLED PRODUCTS	RECYCLED PRODUCTS

Then have a conversation:

1. Did you find it difficult to separate recycled and non-recycled products? Why?
2. What are the differences between recycled and non-recycled products??
3. How similar are recycled and non-recycled products?
4. What would make it easier to distinguish between recycled and non-recycled products?

ACTIVITIES IN CLASSROOM:

1st ACTIVITY: How does the circular economy work?

The supplies you need:

1. Women's pantyhose (nylons) or another polyamide (nylon) product
2. Pictures from the appendix

Divide the students into several groups. Give each group a non-recycled (e.g. women's pantyhose, new packaging) and a recycled product (e.g. recycled nylon), depending on what you have available.

The students look at and feel everything and compare the recycled and non-recycled products. Lead a discussion:

1. Are the two products similar or different? Describe both products.
2. What are the differences between them?
   In the discussion, emphasise the comparable quality of the products.
3. What is the non-recycled product made of?
4. What is the recycled product made of?

Distribute pieces of the circle representing circular economy to the groups of students (Figure14). Their task is to try to make the correct sequence of the links of the circle of the circular economy. They can use the pictures to help them. If they do not understand some of the words or parts of the circle, explain the new concepts or encourage them to use pictograms to help them.

Then give them the pictures showing circular economy using the example of polyamide (nylon) recycling in AquafilSLO company (Appendix 2) (if they wish, they can sort the stages of another company involved in the circular economy – see the recommended reading). Students arrange the pictures in the correct sequence into the circular economy circle.

Figure 14: Example of a compound circle

After the activity, lead a discussion:

1. What does the nylon in the picture look like?
2. What is it made of? What waste is it?
3. How is it processed? What form does nylon take before, during and after processing?
4. Do you think that this nylon is similar to the nylon we know from home/we have observed before, or are they in any way different?

FINAL ACTIVITY: ECO quiz

Hold a quiz to introduce the concept of the circular economy using AquafilSLO company as an example.

Students remain divided into groups. Each question and possible answers are read out. The groups have some time to consult with the rest of the group. The first group to raise the hand answers the question. If they fail to answer correctly, the next group continues. Groups collect points for correct answers. The group with the most points wins. The correct answer is indicated by bold letters.

ECO quiz:

1. Nylon is:

A. made from crude oil.
B. made from a plants.
C. made from animals.

2. The waste we throw in the bin can:
A. disappear.
B. **end up in the sea.**
C. stay in the bin forever.

3. What can we use to replace crude oil in the production of nylon?
A. Nylon Waste.
B. Plants.
C. Oil.

4. AquafilSLO company is engaged in:
A. manufacture of swimwear.
B. processing ECONYL® regenerated nylon from waste materials.
C. manufacture of wool.

5. Which waste does AquafilSLO company produce polyamide (nylon) from?
A. plastic bottles.
B. caps.
C. waste fishing nets, old carpets and textile factory waste.

6. Polyamide (nylon) made in this company is:
A. dirty.
B. worse than nylon, which is made from crude oil.
C. clean and identical to nylon made from crude oil.

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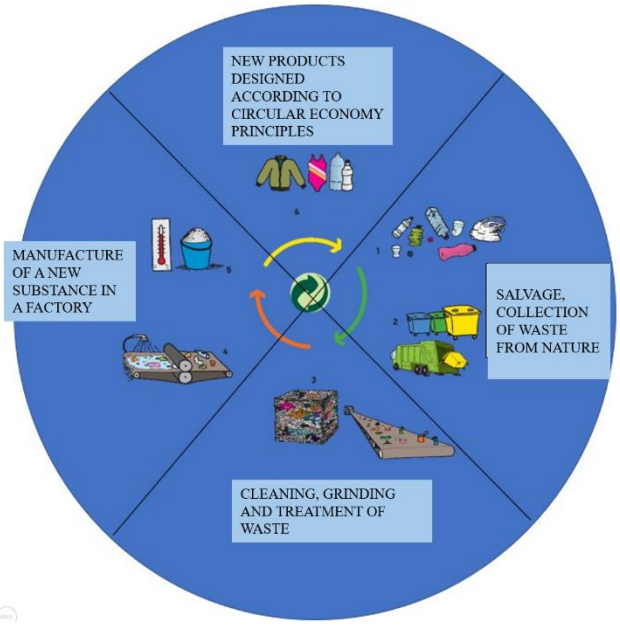
APPENDICES:

Appendix 1

Figure 15: The circle of circular economy



Appendix 2: Pictures of nylon recycling

Figure 16: Rescuing of nylon waste such as fishing nets

Figure 17: Rescuing of nylon waste such as old carpets

Figure 18: Storage of nylon waste rescued around the world

Figure 19: Regeneration of waste into ECONYL® granulate

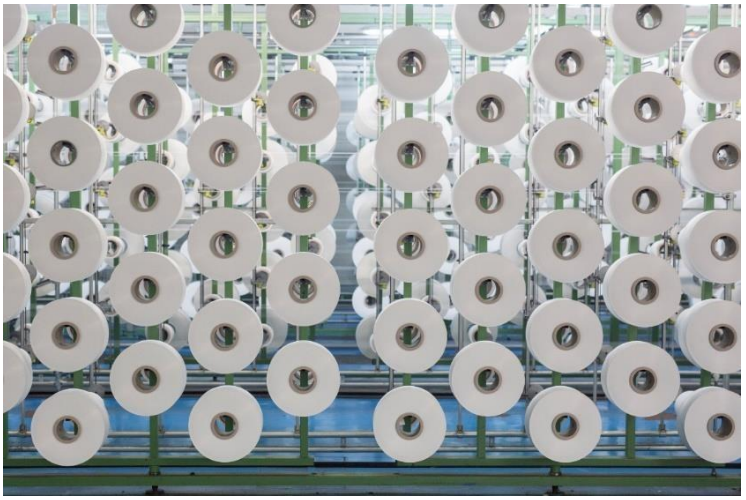


Figure 20: ECONYL® Recycled yarns on packages

Figure 21: ECONYL® Dyed recycled yarns on packages

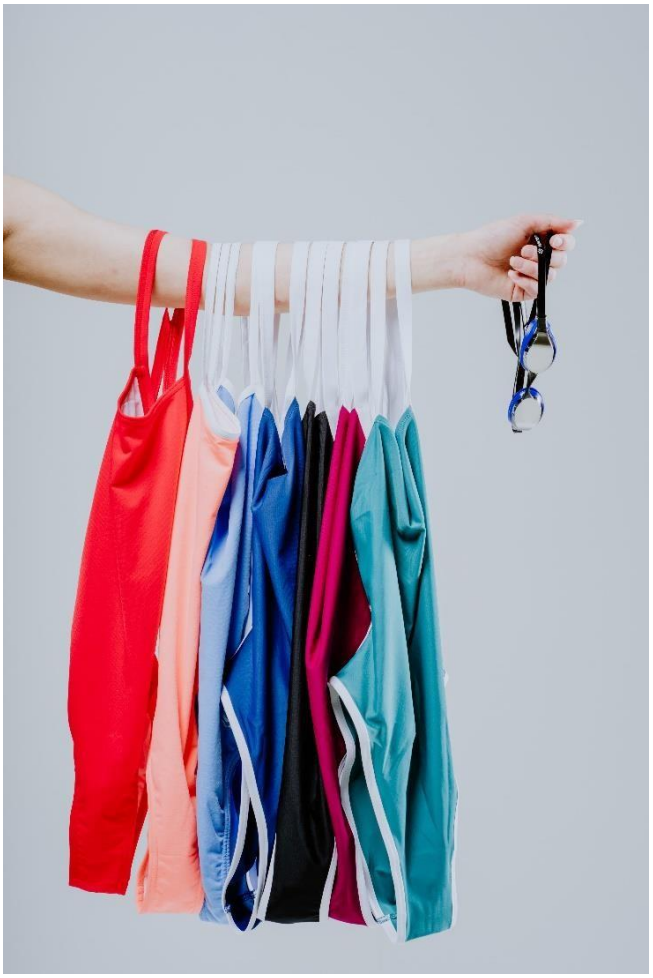


Figure 22: Products made with ECONYL® regenerated nylon

Figure 23: Products made with regenerated ECONYL® nylon

6. Fit for the bin?

EDUCATIONAL PERIOD: 2nd educational period, 4th–5th grade

INTRODUCTION:

Our aim today is to try and use the waste as useful raw materials. Instead of dumping waste into the environments, we recycle them as many times as possible into new products that will be useful again. Thus, we try to reduce the quantity of waste that lands in the environment to the detriment of all living beings in the world, humans included. It also benefits the environment to reuse materials that have already been used, thus saving natural resources. The circulation of materials in various products is called circular economy. In Slovenia, there are companies that recycle waste materials into new products (e.g. hygienic paper, paper towels, bags made of tomato stems, etc.). AquafilSLO company collects waste fishing nets, carpets and industrial waste from all over the world. All this waste is processed into a brand-new material called ECONYL® polyamide, also known as regenerated nylon. It is used in producing ladies' pantyhose, swimwear, backpacks, etc. Activities presented below will show you the journey of waste from the beginning to the reusable product; you will also see the environmental footprint that waste leaves on our planet.

The aim of the learning unit is to understand and compare the linear and circular economies.

NEW CONCEPTS:

Linear economy – traditional economy model that extracts raw materials, uses them to manufacture products and after the end of their life cycle disposes of them as waste.

Circular economy– economy model that recycles and reuses products and materials which are kept in use as long as possible.

Processing – process in which raw materials and semi-finished products are processed, modified or combined using different technological processes.

Nylon – polyamide man-made fibre produced by a chemical process called polymerisation.

INTRODUCTORY STUDENT MOTIVATION:

At the beginning, students are invited to form a circle. Rules of the next activity are explained: Let's pass the ball. Whoever gets the ball must answer the question: »How do you treat waste? How do you treat waste at home?« The person passes the ball to any of their school mates in the circle (to one who has not answered a question yet).

ACTIVITIES IN CLASSROOM:

Educational goals:

- Students think about proper waste management.
- Students learn about proper waste management.
- Students learn about the importance of having a critical attitude towards manufacturing a product and the resources needed to produce it.
- Students learn about sustainable development.
- Students learn what causes pollution in the environment.
- Students can interpret the negative effects of overproduction and overconsumption.
- Students classify resources/products as sustainable or unsustainable.

Duration: 4 school hours (Natural Science Day) or as specific activities which can be carried out during a longer period within various school lessons.

Teaching aids:

- various waste items that children collect in advance and bring with them on the day of the workshops (plastic bottles, bottles, jars, fabric, clothes, caps, can tabs (the aluminium device on the top of a can used to open it), cans, rope)
- A sensory box ECONYL® (by Aquafil company) as an example of recycled nylon
- pictures
- Monopoly money (can also be printed)
- bags/shopping basket
- scissors, glue, strings, crayons/markers, tape

Course of activities:

1st ACTIVITY: TRADE AND SORTING OF WASTE (LINEAR/CIRCULAR ECONOMY)

Prior to implementing activities in classroom, waste materials are collected.

Before entering the workshop, children receive money (printed or from Monopoly) to pay a product. When starting the workshop they first go through a shop where they can buy various items (plastic bottles, bottles, jars, fabric, clothes, caps, can tab, etc.) (Appendix 1).

Next, the students sort the products they have bought into three bins, depending on whether they would put the product in a non-sorted (municipal) waste bin, whether they would reuse it, or whether they would process it into another object/product (waste bin, reuse bin, recovery bin). (Appendix 1)

Explain to the students that if the item were to be placed in the municipal waste bin (as unsorted waste), this would mean that the product's journey would end. This

would illustrate linear economy. If the item is placed in the reuse or recovery bin, it would mean that the product can be reused or made into a new product, which is a demonstration of the circular economy.

2nd ACTIVITY:

The first activity is followed by three different workshops. Each of the workshops demonstrates the path of a waste item that landed in a particular basket.

1st workshop: WHAT TRACES DOES WASTE LEAVE IN THE ENVIRONMENT?

In the first workshop, we show the impact or footprint that waste leaves on our planet.

On the cardboard (board /teaching sheet), Small pictures are arranged in two or three columns. The first column shows pictures of waste and the other two columns show the impact of waste on the environment or on people. The students use strings to connect the pictures to each other, according to the effects the waste leaves on different surfaces in our environment (Appendix 2).

Alternatively, you can use sheets with pictures or a school board on which you attach the pictures and the children connect them with a line they draw with a chalk.

2nd workshop: ECO ACTIVITY

In the second workshop, students learn about reusing products through a game. Using the Eco Activity game, students demonstrate or describe the reuse of a product (with a pantomime or speech).

Play aids:

- Duct tape to mark the boxes (*chalk or string can also be used for different surfaces – outdoor playground, lawn*).
- Reusable objects from the bin.
- Hourglass or stopwatch.

Instructions for playing:

1. Divide the students into two equal groups. If there is an odd number of students, someone can be the referee.
2. The two groups are placed each on their own side of the field.
3. The youngest student in the group is the first to start the game. Both groups play at the same time. One student on each side of the box draws an object from the basket. Their task is to use gestures or an explanation to demonstrate the reuse of this object. They have 1 minute.
4. The other students in the group guess what the student from their group is demonstrating or explaining.

5. Each box is labelled with the way in which the student has to present the object (explanation or pantomime). The first student can choose himself or herself.
6. If the group guesses correctly, they can move one box forward. Otherwise, they stay in the same box.
7. The first group to reach the target wins.
8. It is recommended that the number of boxes is adapted to the number of students in the groups (*example*: *There are 8 students in a group, so we need 8 boxes, 4 on each side. See Appendix 3.).*

3rd workshop: FACTORY

The third workshop will demonstrate waste processing through the example of any company, such as AquafilSLO (from nylon waste to ECONYL® regenerated polyamide (nylon)).

The workshop contains three learning centres through which the students walk.

1st learning centre:

On the table there are three boxes of waste materials (e.g. fishing nets, carpets, industrial textile waste, plastic bottles, aluminium, paper, etc.). The students reach with their hands into each of the boxes and find out what each box contains. The solutions are written under the lid (Appendix 4).

2nd learning centre:

Students watch a video/pictures of AquafilSLO company showing how waste is transformed into nylon ECONYL® (Appendix 5, the video can be found on the website: https://www.youtube.com/watch?v=52xw77dqfAg). Arrange the different stages of product recycling on a table (e.g. samples of nylon in different forms from the AquafilSLO company; cardboard, plastic, paper, wood – in different stages of recycling).

3rd learning centre:

Students see and feel the finished products created by processing waste materials (swimwear, backpack, bag (recycled polyamide - nylon ECONYL®) packaging, promotional material, decorative products, etc.).

3rd ACTIVITY: WHICH WASTE CAN BE RECYCLED?

As a final activity, the students will have a workshop where they will transform a selected waste product into a new product, which must be of practical use.

Examples: earrings and belts made of can tabs, necklaces made of bottle caps, cloth bags (Appendix 6).

Prepare a variety of supplies on the table:

- scissors,
- glue, glue gun,
- a pair of pliers,

- markers.

In the final part, students can display their work and see the work of their classmates.

Discussion questions:

1. What did we do with the waste we bought in our shop?
2. What do you think happens to most of the world's waste? Which bin does it go in?
3. Which way of waste disposal route do you think is the most appropriate? Why?
4. How will you manage with your waste now?

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APPENDICES:

Appendix 1

Figure 24: Example of shop design and layout

Figure 25: Example of making and setting up waste bins

Appendix 2: Pictures for the first workshop

Figure 26: Example of carrying out an activity What traces does waste leave behind in the environment?

Appendix 3

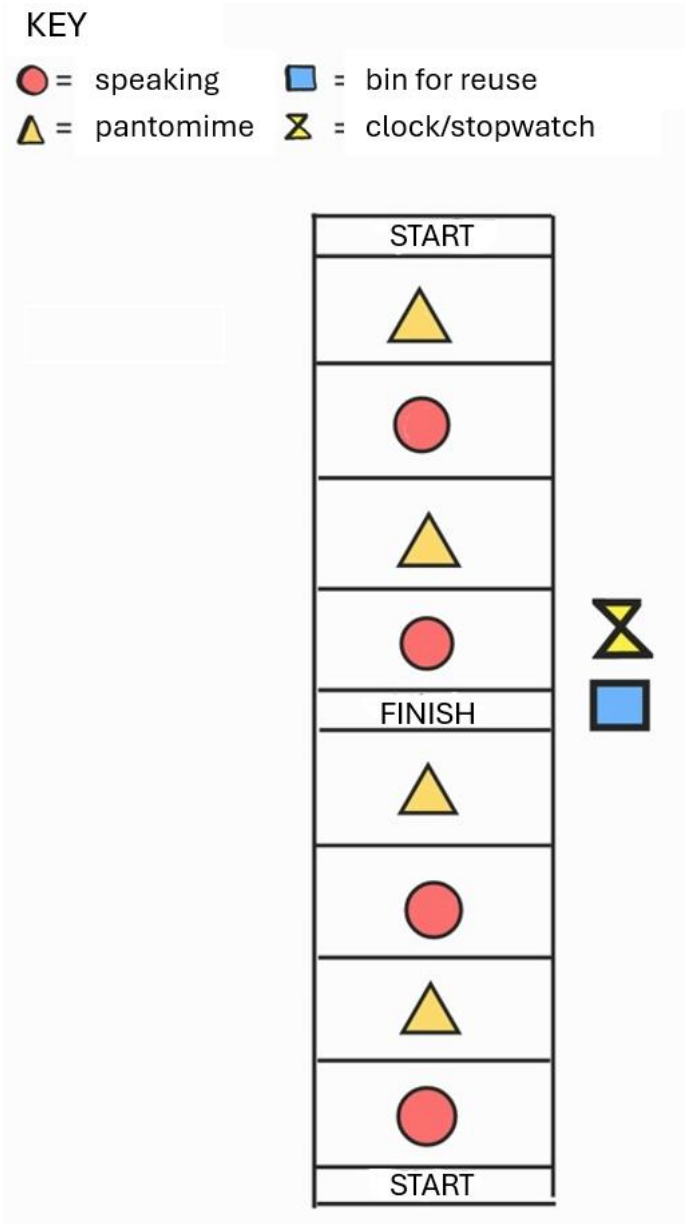


Figure 27: Template for the game Eco activity

Appendix 4

Figure 28: Example of the activity What is hidden in the box?

Appendix 5

Figure 29: Example of an improvised factory model with nylon regeneration.

Appendix 6: Examples of waste processing

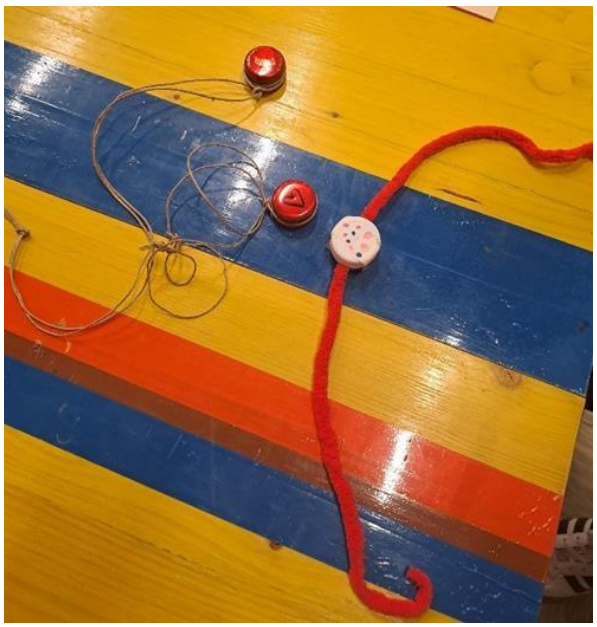


Figure 30: Example of recycled waste – necklaces

Figure 31: Example of recycled waste – baseball

Figure 32: Example of recycled waste – telescope

Figure 33: Example of recycled waste – tap

Figure 34: Example of recycled waste – baseball

Figure 35: Example of recycled waste – drum (left) and rainfall gauge (right)

Appendix 7

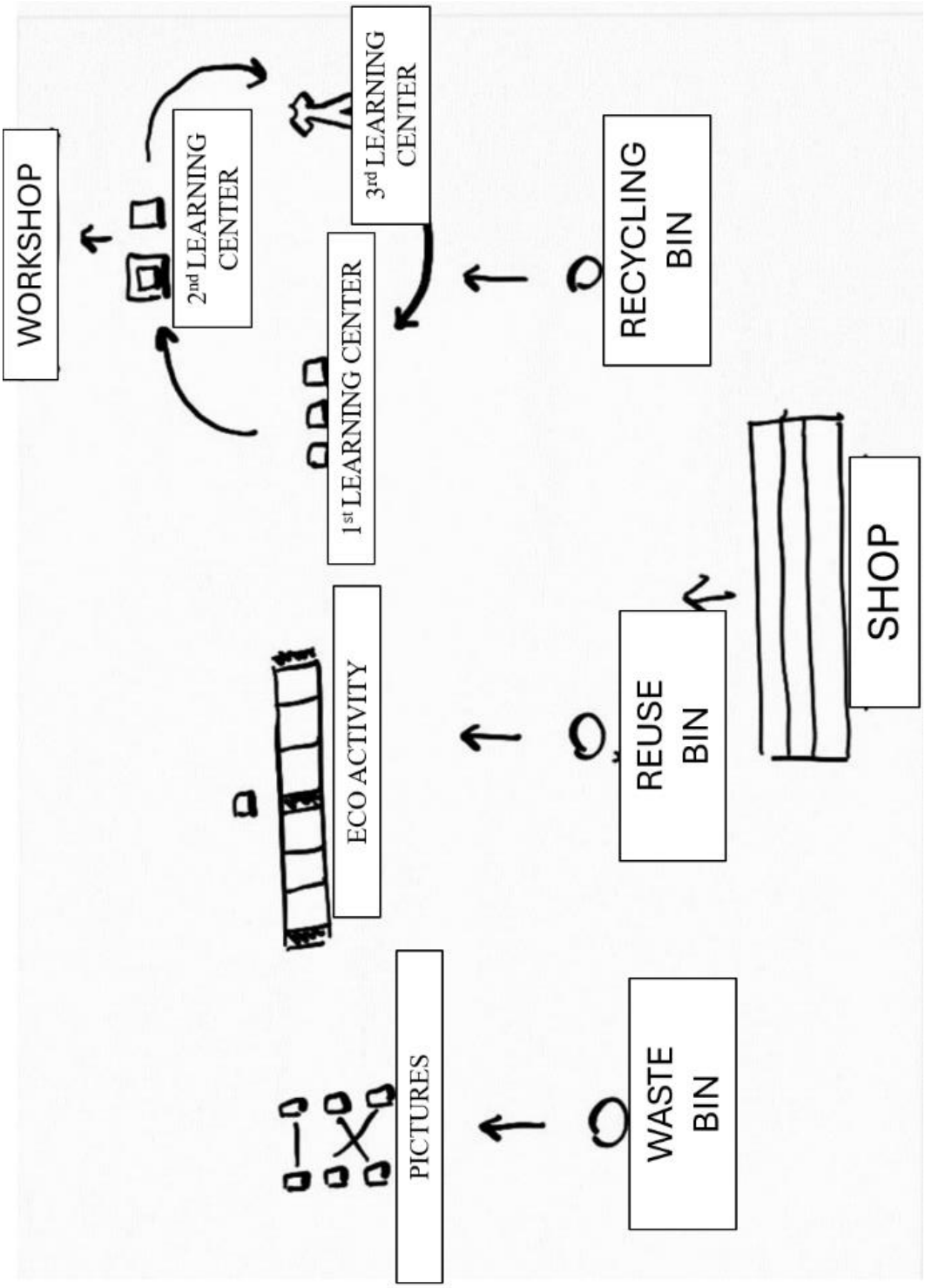


Figure 36: Schematic illustration of workshop

7. Applied chemistry

EDUCATIONAL PERIOD: Third educational period, 8th and 9th grades

INTRODUCTION:

Nylon is a polyamide first produced in the 1930s by American chemist Wallace Hume Carothers. In 1939, ladies' pantyhose (nylons) were first produced and sold. Nylon is similar in properties to silk, but much cheaper and more readily available.

The Aquafil company has been producing polyamide (nylon) since 1965 and part of it called AquafilSLO is located in Slovenia. Since 2011 the AquafilSLO company has also produced regenerated nylon ECONYL®. Their aim is to produce recycled polyamide (nylon) from fishing nets, textile floor coverings and some other textile waste, which is cleaned and broken down into its components and their materials reused to produce recycled polyamide fibres.

Chemistry deals with a variety of compounds that are often thought of as man-made compounds, and when thinking of chemistry few people think of sustainable development or the circular economy. But chemistry is part of the process of recycling polyamide (nylon) and other substances, which are then reused as the same products or to make a new product.

NEW CONCEPTS:

Polyamide polymer - a polymer in which repeating monomers are linked together to form a longer chain by a peptide or amide bond.

Amide bond - a covalent bond formed by bonding a carboxyl group of one molecule and an amino group of another molecule. This process releases a water molecule.

Nylon – is a thermoplastic material. It is a polyamide which means that it is made up of monomers that are bound together by a peptide bond to form a polymer.

Recycled polyamide – nylon ECONYL® – correct chemical name is polyamide 6. Reclaimed polyamide (nylon) is processed by reclaiming products at the end of their lifespan (fishing nets and textile floor coverings) and pre-consumer nylon waste such as fabric scraps from mills

AquafilSLO – the largest producer of polymers and man-made fibres in Slovenia. It produces polyamide (nylon) for the clothing and flooring industries.

Monomer – a small molecule that can chemically bond with other monomers to form polymers.

INTRODUCTORY MOTIVATION FOR STUDENTS:

Have you ever wondered what clothes are made of? How are some materials made? Are there sustainable solutions for producing these materials? Together, we will examine all this and learn about it in this lesson.

Did you know that there are natural and man-made fibres? Actually, you've already learnt about this in home economics classes, but in chemistry we're going to look at man-made fibres in a little more detail. In previous lessons we have already talked about polymers, namely condensation polymers, but today we will talk about another variety of polymers: polyamide polymers. In the worksheet that you will work through during the experiment, and in the consolidation exercises at the end you will get a lot of useful information about polyamide (nylon) and how it is made in a Slovenian factory. Now, let's get under way and let our journey into the world of experiments begin and take place in a pleasant environment and atmosphere.

ACTIVITIES IN CLASSROOM:

Educational goals:

- Learn about the reaction of polyamide (nylon) synthesis.
- Understand the formation of polyamide (nylon).
- Activities carried out: a student is able to explain by example how amide bonds form.
- Learn about the industrial production of polyamide (nylon).
- Apply appropriate experimental techniques in an experiment.
- The student is able to relate chemistry to sustainable development.
- The student can apply knowledge of the circular economy to their own work.

Duration:

- In case of demonstrating the experiment:15 min.
- If the experiment is carried out by students: 30–35 min.
- If we just look at the video footage: 5 min (link to video: https://www.youtube.com/watch?v=1nv2gYofoQE

Teaching aids:

- Teacher worksheet
- Student worksheet
- Computer and projector
- Chemicals listed on the worksheet
- Laboratory protective equipment

Course of activities:

The lesson starts with an introductory motivation for the students. This brings the topic closer to the students and sets the scene for later activities.

To start with, the teacher decides whether to run the experiment as a demonstration, group work or just show the video during the lesson. This decision influences the timing of the lesson. Let's take the example that the experiment is a group work. The teacher distributes worksheets to the students and prepares the chemicals for the experiment.

The students carry out the experiment and write their observations and conclusions on the worksheet. After the experiment, they discuss the results with the teacher and answer revision questions.

For project work or homework, they can do their own experiment, aiming at sustainable consumption and the circular economy in chemistry, or how a polyamide (nylon) could be used in manufacturing a product, where they have to be as innovative as possible.

Discussion questions useful as revision questions:

1. What is the difference between ECONYL® recycled polyamide (nylon) and regular polyamide (nylon)?
2. Which waste materials is recycled polyamide (nylon) obtained from?
3. What is the name of the bond formed between two monomers?
4. What is polyamide (nylon) used for?
5. Give one example of how polyamide (nylon) could be used to manufacture a product. Be as innovative as possible.

Project work: Students carry out their own experiment aimed at sustainable consumption and the circular economy, when experimenting in chemistry.

REFERENCES:

- *Program osnovna šola. Kemija. Učni načrt. (Curriculum. Primary school curriculum. Chemistry*.) (2011). Ministrstvo za šolstvo in šport: Zavod RS za šolstvo

RECOMMENDED READING:

Links to websites with more information on circular economy and sustainability:

- https://zssszaupnikvzd.si/baza-znanja/podnebne-spremembe/krozno- gospodarstvo/krozno-gospodarstvo/
- https://www.kimi.si/krozno-gospodarstvo-kimi/
- https://ekosola.si/
- https://www.stat.si/Pages/cilji
- https://sl.wikipedia.org/wiki/Trajnostni_razvoj

APPENDICES:

Appendix 1: Student's worksheet

POLYAMIDE (NYLON) SYNTHESIS

INTRODUCTION:

Nylon is a polyamide first produced in the 1930s by American chemist Wallace Hume Carothers. In 1939, long transparent women's stockings, called ladies' tights (nylons) were first produced and sold. Polyamide (nylon) is similar in properties to silk, but much cheaper and more readily available.

The Aquafil company has been producing polyamide (nylon) since 1965, and the part of the company called AquafilSLO is located in Slovenia. Since 2011 the AquafilSLO company has also produced regenerated nylon ECONYL®. Their aim is to produce recycled polyamide (nylon) from fishing nets, textile floor coverings and some other pre-consumer nylon waste, which is cleaned and the nylon mollecules are broken down into their building blocks and then reused to produce ECONYL® recycled polyamide.

We are going to do an experiment for which you need what's shown in the Table 6.

Table 6: **A list of supplies and chemicals**

SUPPLIES	CHEMICALS
2 beakers	20 mL cyclohexane 
2 x 30 mL measuring cylinders	2 mL adipyl dichloride
Glass rod	20 mL sodium hydroxide 
Tweezers	1 g hexane-1,6-diamine
Hourglass	

SAFETY AT WORK:

Safety is of paramount importance when carrying out an experiment, as you are handling hazardous chemicals. You must be dressed in a lab coat, wear gloves and safety goggles. If you have long hair, it must be tied in a ponytail.

GOAL:

- Synthesis of polyamide (nylon) in the laboratory.

WORK COURSE:

1. Use two beakers. In the first beaker, measure 20 mL of sodium hydroxide with a measuring cylinder.
2. Add 1 g of hexane-1,6-diamine into it and mix well.
3. Into the second beaker measure 20 mL of cyclohexane, using a measuring cylinder.
4. Add 2 mL of adipyl dichloride and mix well.
5. Carefully pour the mixture from the second beaker into the mixture in the first beaker.
6. A phase boundary is formed between the two liquids.
7. Using tweezers, grasp the phase boundary and start to thread it onto the glass rod.
8. Continue this process until one component runs out.
9. Wash the resulting product under running water.
10. The final product is nylon 6,6.

Table 7: **Observations and conclusions**

OBSERVATIONS	CONCLUSIONS

Write the chemical reaction that takes place in the experiment:

Appendix 2: Teacher Worksheet

POLYAMIDE (NYLON) SYNTHESIS

INTRODUCTION:

Nylon is a polyamide first produced in the 1930s by American chemist Wallace Hume Carothers. In 1939, long transparent women's stockings, called ladies' tights (nylons), were produced and sold. Polyamide (nylon) is similar in properties to silk, but much cheaper and more readily available.

The Aquafil company has been producing polyamide (nylon) since 1965, and the part of the company called AquafilSLO is located in Slovenia. Since 2011 the AquafilSLO company has also produced regenerated nylon ECONYL®. Their aim /objective is to produce recycled polyamide (nylon) from fishing nets, textile floor coverings and some other pre-comsumer nylon waste, which is cleaned and the nylon mollecules are broken down into their building blocks and then reused to produce ECONYL® recycled polyamide.

For the experiment that will be carried out you need items from the table 8.

Table 8: **A list of supplies and chemicals**

SUPPLIES	CHEMICALS
2 beakers	20 mL cyclohexane 
2 x 30 mL measuring cylinders	2 mL adipyl dichloride 
Glass rod	20 mL sodium hydroxide 
Tweezers	1 g hexane-1,6-diamine 
Hourglass	

SAFETY AT WORK:

Safety is of paramount importance when carrying out an experiment, as you are handling hazardous chemicals. You must be dressed in a lab coat, wear gloves and safety goggles. If you have long hair, it must be in a ponytail.

GOAL:

- Synthesis of polyamide (nylon) in the laboratory

WORK COURSE:

1. Use two beakers. In the first beaker, measure 20 mL of sodium hydroxide with a measuring cylinder.
2. Add 1 g of hexane-1,6-diamine into it and mix well.
3. Measure 20 mL of cyclohexane into the second beaker, using a measuring cylinder.
4. Add 2 mL of adipyl dichloride and mix well.
5. Carefully pour the mixture from the second beaker into the mixture in the first beaker.
6. A phase boundary is formed between the two liquids.
7. Using tweezers, grasp the phase boundary and start to thread it onto the glass rod.
8. Continue this process until one component runs out.
9. Wash the resulting product under running water.
10. The final product is nylon 6,6.

Table 9: **Observations and conclusions**

OBSERVATIONS	CONCLUSIONS

Write the chemical reaction that takes place in the experiment:

8. Circular economy: AquafilSLO – an example of good practice, and ECONYL® regenerated nylon

EDUCATIONAL PERIOD: third educational period, 7th to 9th grades

INTRODUCTION:

Today, we produce many different products, and they require an increasing variety of raw materials, most often from natural sources. As all natural resources are not unlimited, they should not be overused or exploited irrationally. Unfortunately, some of them are already running out, as nature cannot replenish them as quickly or in the quantities we consume. To prevent this, also we as individuals have to behave sustainably when we buy and use products. The same applies to the companies producing them. We are contributing to this by changing our product manufacturing strategy from linear to circular economy. We will see this below.

The aim of this learning unit is to distinguish between linear and circular economy and to learn about a Slovenian company that is a good example of circular economy, AquafilSLO.

NEW CONCEPTS:

Linear economy – an economy where a resource or material is used to make a product or service, but after its use the product or packaging is thrown away

Circular economy – a way of organising production and consumption based on the circulation of materials. The resources and materials used are kept for as long as possible – In the same form or in a modified form

Recycling – recovery of used waste materials in the production process

Polyamide 6 (nylon 6) – man-made material used for clothing and furnishings

Recycled polyamide – nylon ECONYL® – polyamide (nylon) with the same properties as newly produced polyamide, but produced in a sustainable way

AquafilSLO – pioneer of circular economy, the largest producer of polymers and man-made fibres in Slovenia and the only one specialising in the production of recycled polyamide – ECONYL® nylon for clothing and carpet industries.

INTRODUCTORY STUDENT MOTIVATION:

What is linear economy? What is circular economy? What are natural resources? What is waste? How much waste do we produce yearly? How can we reduce the quantity of waste?

ACTIVITIES IN CLASSROOM:

Educational goals:

Students learn and deepen their knowledge of linear and circular economies.

- Students learn the difference between linear and circular economies.
- Students learn about an example of good practice of circular economy, the company AquafilSLO.
- Students develop critical thinking about circular and linear economies.

Duration:

- Duration of the whole activity: 45 minutes
- Time for introductory motivation (linear and circular economies): 20 minutes
- Time to watch the video: 5 minutes
- Discussion time: 20 minutes

Teaching aids:

- Computer with internet access
- Speakers
- Projector
- Board or screen
- Enlarged printed template of the linear economy (Appendix 1)
- Enlarged printed template of the circular economy (Appendix 2)
- Materials found at school or at home (e.g. plastic bottle, newspaper, it can also be an ECONYL® box).

Course of activities:

1. Students look at Figure 40 (a schematic of the linear economy process). The teacher shows them how linear economy is designed. Together they come to the conclusion that in the case of circular economy, much less or almost no waste is produced and instead of using natural resources as raw materials for

the production of products, they reuse, repair, remanufacture and share existing products that would end up in the “rubbish bin” in linear economy.

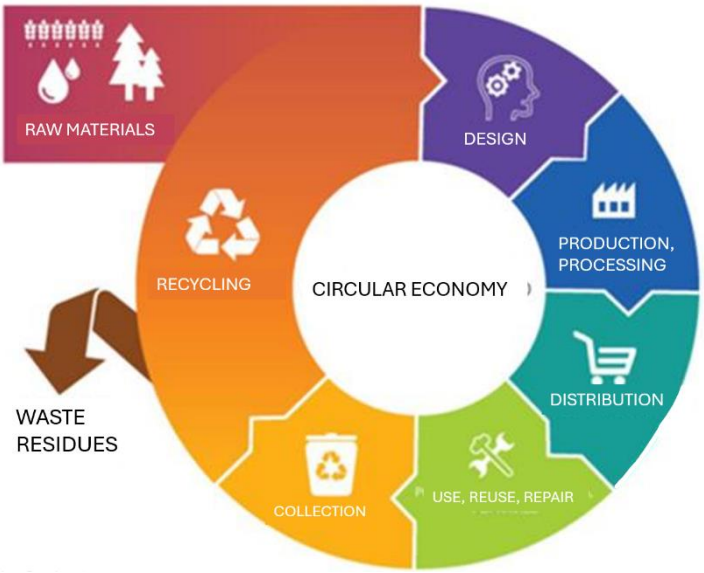


Figure 37: Schematic presentation of circular economy processes (Kimi, 2023).

ACTIVITY: Students sort materials that can be found at home or at school according to the circular economy template (Appendix 2).

Examples of products and materials that can be used:

- Newspaper, paper pulp, torn newspaper. etc.
- Plastic bottle, plastic bottle parts, etc.

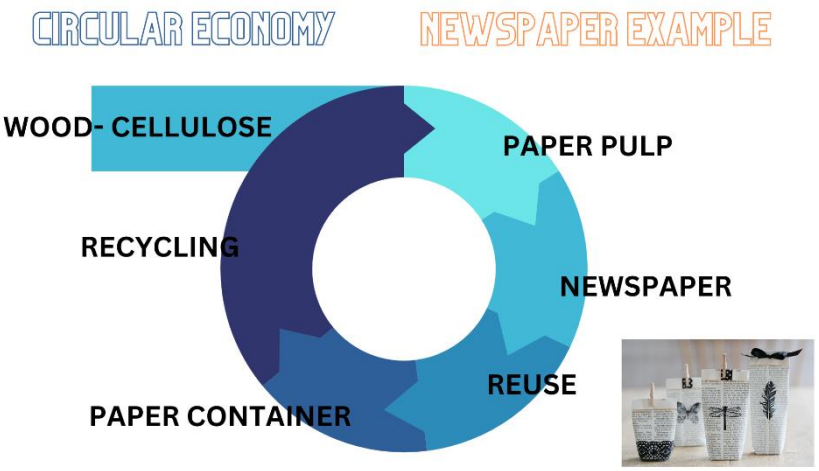


Figure 38: Example of successfully sorted newspaper according to template 2

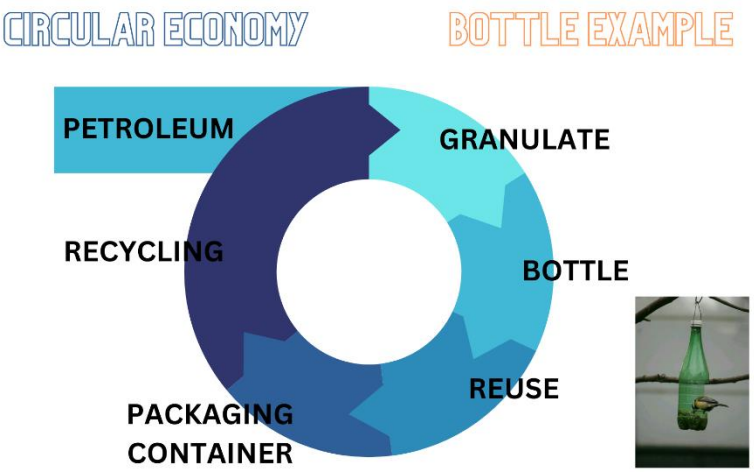


Figure 39: Example of successfully sorted plastic bottles according to template 2

After the activity, the question is asked, where is the "beginning" and the "end" in the circular economy process? The beginning is in product design, there is *no end.*

2. The teacher asks the students the question: "Why are we developing circular economy?" From the answer obtained, it can be summarised that we want to act sustainably, i.e. to use as little natural resources as possible and to produce as little waste as possible. The teacher tells us that in Slovenia, there already are a number of companies that are working according to the circular economy principle, and one of them is AquafilSLO with its ECONYL® line. The teacher says that they deal with polyamide (nylon) and that the students have heard about it in chemistry when they were learning about polymers or in home economics when they were learning about textiles.
3. The teacher announces that they will learn more about circular economy and recycled polyamide (nylon) by watching the video (plays the video, which is available online through the link).
4. After watching the video, the teacher divides the students into 4 groups. Each group receives a question, which they discuss within the group and find an answer to. After a 5-minute discussion within the groups, the leader of each group presents their questions, findings and reflections to the others.

Questions for discussion

1. How would you motivate large companies to change their operations from linear to circular?
2. What are the environmental benefits of circular economy?
3. Which do you think is better for the environment, linear economy or circular economy?

4. Design a company based on circular economy (the material they use should be paper/plastic/textile/aluminium/cartons/computer equipment).
5. Do you know any other examples of good practice in circular economy in Slovenia? What is the difference between recycling and circular economy?
6. How can we keep a product in use for as long as possible? What can we do with a product?

REFERENCES:

- Evropski parlament. (24.5.2023). *Krožno gospodarstvo: definicija, pomen in prednosti*. https://www.europarl.europa.eu/news/sl/headlines/economy/20151201STO05603/kroz no-gospodarstvo-definicija-pomen-in-prednosti / https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits (ENG)
- Ekošola. (2022). *Krožnost je naša priložnost. (Circularity is our opportunity.)* https://ekosola.si/kroznost-je-nasa- priloznost-22-23/
- Kimi. (2023). *Krožno gospodarstvo.* https://www.kimi.si/krozno-gospodarstvo-kimi/
- *AquafilSLO*. (2022). https://www.aquafil.com/slovenija/

RECOMMENDED READING:

- https://ekosola.si/wp-content/uploads/2022/09/Kro%C5%BEnost_OPIS-PRIMERA_Regenerirani-nylon-ECONYL.pdf
- https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circ ular-economy-definition-importance-and-benefits?&at_campaign=20234-Economy&at_medium=Google_Ads&at_platform=Search&at_creation=RSA&at_goal=TR_G&at_audience=circular%20economy%20action%20plan&at_topic=Circular_Economy&at_location=SI&gclid=Cj0KCQjw0tKiBhC6ARIsAAOXutn216RTsDXwBmGKtztB7vPUpDGB7HNnfHDq6zM9YJlk77_jdEkFPxAaAlnUEALw_wcB

APPENDICES:

Appendix 1

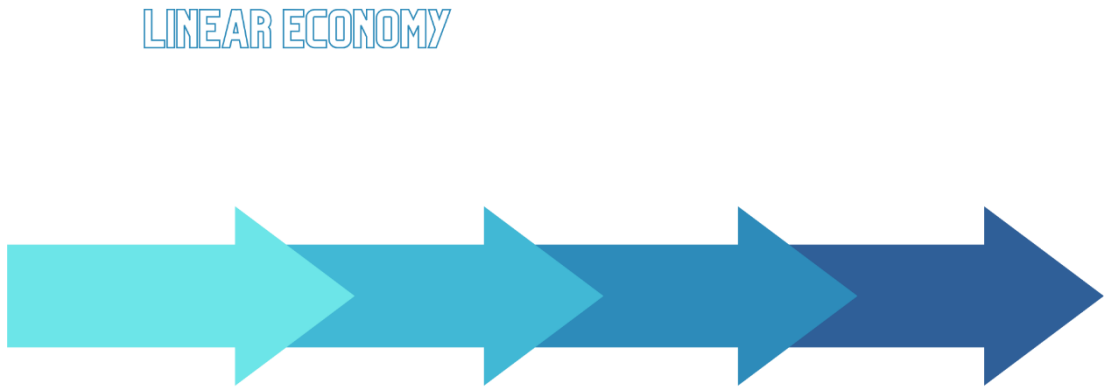


Figure 40: Template 1

Appendix 2

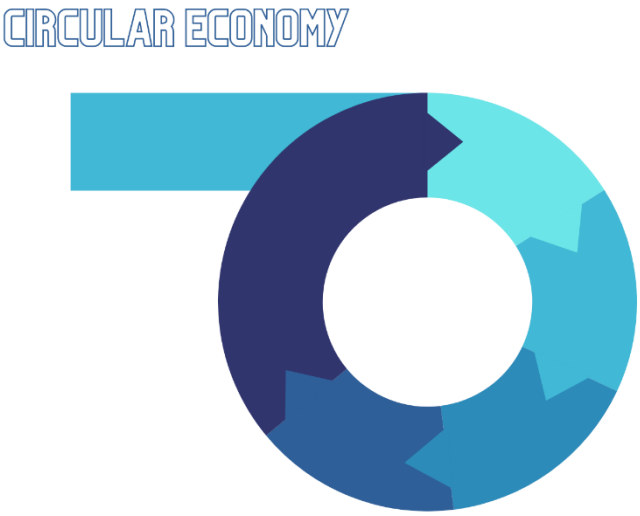


Figure 41: Template 2

9. A sustainable start-up

EDUCATIONAL PERIOD: secondary school

INTRODUCTION:

The textiles and clothing industry is a major consumer of water, energy and hazardous chemicals. This *Sustainable Start-up* lesson aims to encourage students to think about sustainable and green entrepreneurship. By designing a start-up that regenerates waste, they develop critical thinking, look for appropriate solutions and realise that they can design a textile company that will operate in a sustainable way.

NEW CONCEPTS:

Regeneration – the process by which waste becomes part of a new cycle of manufacturing products of the same quality

INTRODUCTORY STUDENT MOTIVATION:

Everyone talks about sustainability these days, but what exactly is it? What are the benefits and what are the challenges of operating in a sustainable way? How do you yourself act sustainably and where do you think your opportunities for improvement lie?

ACTIVITIES IN CLASSROOM:

Educational goals:

Students:

- plan their sustainable start-up;
- compare different businesses with each other on the economic, ecological and social dimensions of sustainability.

Duration: 1–2 school hours

Teaching aids: Worksheet 1, posters, markers

Course of activities:

The teacher divides the students into groups of 4, gives them worksheets (Worksheet 1), posters and markers. In groups, students start thinking like sustainable entrepreneurs. They are guided by a set of questions, which they can supplement with their own. They write down their ideas on the reverse page of the worksheet, in the space for notes. Once they have worked out their ideas, they produce a poster which they use to convince their classmates that theirs is the best business plan worth pursuing.

REFERENCES:

- Ekošola. (No date). *Krožno gospodarstvo.* https://ekosola.si/wp-content/uploads/2019/11/Kro%C5%BEno-gospodarstvo_Ekokviz-S%C5%A0-19- 20.pdf

RECOMMENDED READING:

- Ghezzo, P. and Vannucci, R. (No date). *Ekološko snovanje v tekstilni industriji (Ecological design in textile industry)* http://www.ecosign-project.eu/wp-content/uploads/2018/09/TEXTILE_UNIT08_SLO.pdf
- Ekošola. (No date). *Krožnost je naša priložnost.* https://ekosola.si/wp-content/uploads/2022/09/Kro%C5%BEnost_OPIS-PRIMERA_Regenerirani-nylon- ECONYL.pdf
- *Start:up Slovenia.* (No date). https://www.startup.si/

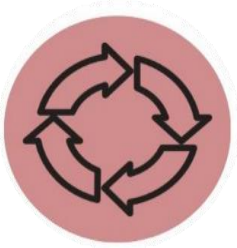
APPENDICES:

Appendix 1: Worksheet

The textiles and clothing industry is a major consumer of water, energy and hazardous chemicals. In groups of 4, design a start-up company dealing with waste and waste recovery.
The following questions should help you to design the company and create the poster.

1. What are the characteristics of start-ups?
2. What do you need to do before setting up a start-up?
3. Why have you chosen a start-up company with circular economy as its main focus, rather than a recycling economy? What are the potential benefits and challenges?
4. How big will your start-up company be? What will be the number of employees, working hours?
5. What types of waste will you be dealing with?
6. Will the company produce a finished product or raw material?
7. How will you obtain the waste and where will you store it? Which mode of transport will you use?
8. Is the waste immediately recoverable or does it need to be split to its basic components first?
9. Will you use chemical or physical recovery processes?
10. Think also about the circularity of your business. How much water, electricity will you use, how many waste by-products will you generate and how could you use them further?
11. Who will you sell your products to, how big will the market be?
12. Who will take care of advertising your business?
13. Will you have an agreement with your customers to return old products for remanufacture?

10. Basics of circular economy



EDUCATIONAL PERIOD: secondary school

INTRODUCTION:

Circular economy is the process that reduces the impact of exploiting natural resources by focusing on the reuse, recycling and repair of products.

Through the following activity, the lesson aims to review the key concepts related to circular economy. This topic is important because human activity already goes beyond the limits of safe environmental interventions.

NEW CONCEPTS:

Linear economy – characterised by the massive extraction of raw materials to make products that become waste at the end of their life cycle

Circular economy – the process of reducing the impact of exploiting natural resources by focusing on the reuse, recycling and repair of products

Fast fashion – the trend of buying new clothes over and over again

3R (reduce, reuse, recycle) – basic principles of circular economy

Regeneration – a system in which waste is part of a new cycle of making products of the same quality

Sustainable Development Goals (SDGs) – call to action for all countries to promote prosperity while protecting the planet

INTRODUCTORY STUDENT MOTIVATION:

Which separate waste collection containers are you familiar with? What waste goes into each container? Have you ever tried to recycle and reuse waste?

ACTIVITIES IN CLASSROOM:

Educational goals:

Students:

- understand the importance of circular economy;
- compare the linear and circular economies;
- learn about the regeneration process.

Duration: 1 school hour

Teaching aids: learning cards with questions on the basics of the circular economy

Course of activities:

1. Start the classroom activity by dividing the students into pairs.
2. Each pair is given a set of question cards on the basics of circular economy.
3. Students take turns to draw cards from the pile with the questions facing up. The student who pulls out a card reads the question to which the other student in the pair answers. Together they check the correct answer on the other side of the card.
4. This activity takes about 20 min.
5. After the activity, the teacher answers the questions on the cards jointly with the students, gives a more detailed explanation and answers any questions the students may have.
6. The activity can be adapted and used as an introductory motivation. In this case, do not focus on reviewing the correct answers with students and giving them additional explanations.

REFERENCES:

- Ekošola. (No date). *Krožno gospodarstvo.* https://ekosola.si/wp-content/uploads/2019/11/Kro%C5%BEno-gospodarstvo_Ekokviz-S%C5%A0-19- 20.pdf

RECOMMENDED READING:

- Ekošola. (No date). *Krožno gospodarstvo.* https://ekosola.si/wp-content/uploads/2019/11/Kro%C5%BEno-gospodarstvo_Ekokviz-S%C5%A0-19- 20.pdf
- United Nations Organization. (2023). *Sustainable Development Goals.* https://unis.unvienna.org/unis/sl/topics/sustainable_development_goals.html

APPENDICES:

Appendix 1

WHAT IS RECYCLING?	**WHAT ARE THE BASIC PRINCIPLES OF CIRCULAR ECONOMY? (3R)**
Recycling is the processing of waste materials to create new ones.	Reduce, reuse and recycle.
EVERY EUROPEAN PRODUCES 1 TONNE OF WASTE PER YEAR. TRUE OR FALSE?	**HOW CAN WE REDUCE THE AMOUNT OF WASTE WE THROW AWAY?**
False, every European produces 5 tonnes of waste per year.	- Avoid buying disposable products - Plan and shop wisely - Recycle and repair - Use a reusable bottle - Use a reusable shopping bag - Use e-invoices

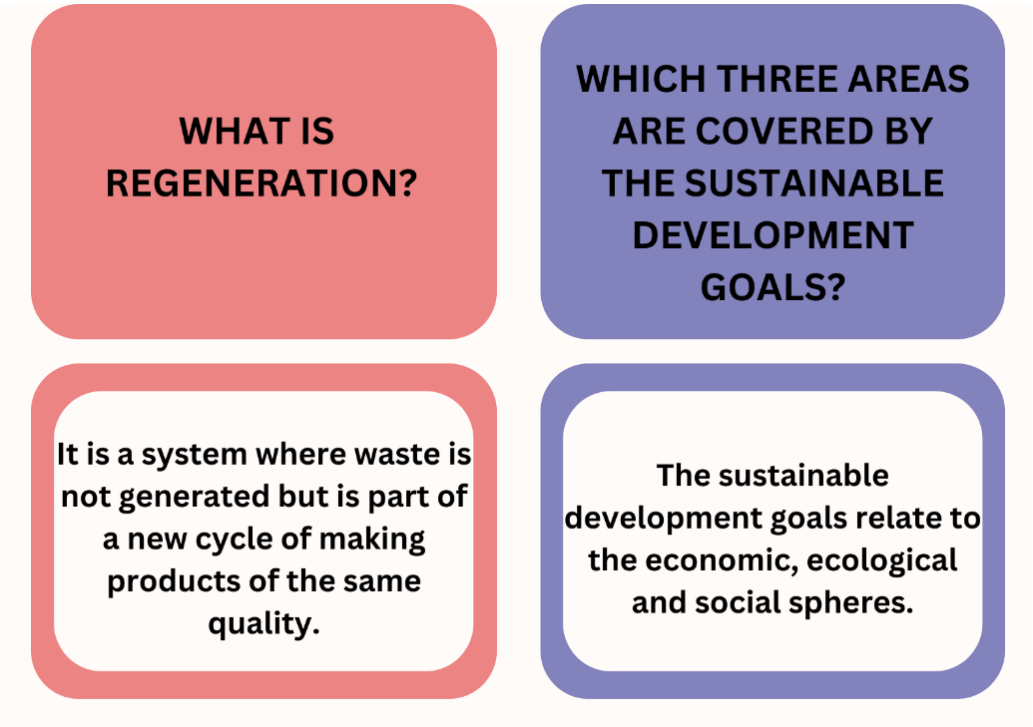
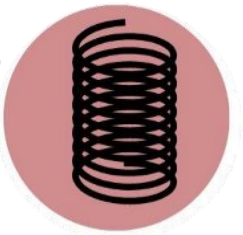


Figure 42: Learning cards with questions on basics of circular economy

11. Polyamide fibre stretching



EDUCATIONAL PERIOD: secondary school

INTRODUCTION:

Polyamide fibres are man-made textile fibres that are very fine, extremely strong and more elastic than any natural fibre. They do not stretch according to Hooke's law, which describes the action of forces on flexible bodies. Hooke's law states that the force acting on a spring and the spring's elongation are proportional. So for a force two times, three times ... greater, the elongation will be two times, three times greater. The forces are equal if they produce equal changes on the same elastic body.

The lesson using the following activity is designed to introduce the characteristics of polyamide fibres and to understand that they do not stretch according to Hooke's law.

NEW CONCEPTS:

Stretching – the process of changing the shape of a body due to the action of a force

Polyamide – man-made substance used mainly for the manufacture of man-made fibres

Hooke's law – explains the relationship between force and elongation under load and states that the force acting on a spring and the elongation of the spring are proportional

INTRODUCTORY STUDENT MOTIVATION:

What are our clothes made of? What do we do with the clothes we no longer need? Which industries use textile fibres?

ACTIVITIES IN CLASSROOM:

Educational goals: **Students:**

- Learn about the characteristics and uses of polyamide fibres,
- Understand that polyamide fibres do not stretch according to Hooke's law,
- Analyse a graph of elongation in reference to tensile force.

Duration: 1 school hour

Teaching aids: video on polyamide stretching and worksheet 1

Course of activities:

1. Show students a video on polyamide stretching (Link: https://www.canva.com/design/DAFfyL66_zk/XOXsxUnC4NnwVn7z2fnYow/watch?utm_content=DAFfyL66_zk&utm_campaign=designshare&utm_medium=link&utm_source=editor).
2. Then give each student a worksheet to complete independently.
3. Their independent work will take between 20 and 25 minutes.
4. At the end, the teacher reviews the solution on the worksheet with the students and answers any questions they may have.

REFERENCES:

- Encyclopaedia Britannica. (2023). *Polyamide.* https://www.britannica.com/topic/industrial-polymers-468698/Polyamides
- Grubelnik, L., Zupan, D., Gosak, M., Markovič, R., Ketiš, B., Repnik, R. in Jug, M. (No date). *I-učbenik za fiziko v 8. razredu osnovne šole. (Physics textbook for the 8th grade of primary school)* Ministrstvo za izobraževanje, znanost in šport: Zavod RS za šolstvo https://eucbeniki.sio.si/fizika8/index.html

RECOMMENDED READING:

- Jamšek, S., Sajovic, I., Godec, A., Vrtačnik, M., Wissiak Grm, K., Boh, B. in Blažar, S. (b. d.). *I-učbenik za kemijo v 9. razredu osnovne šole. (Chemistry textbook for the 9th grade of primary school),* Ministrstvo za izobraževanje, znanost in šport: Zavod RS za šolstvo https://eucbeniki.sio.si/kemija9/index.html

Appendices:

Appendix 1: Worksheet

POLYAMIDE FIBRE STRETCHING

Watch the video on polyamide (nylon) stretching and answer the following questions.

1. Write down the main characteristics of polyamide fibres.

_____

2. What is the relationship between nylon and polyamide?

_____

3. Use the graph below to answer the questions.
    a. Is the elongation of polyamide knitted fabric linear? YES / NO
    b. Does Hooke's law apply to the stretching of polyamide knitted fabrics? YES / NO
    c. At which force do the polyamide knitted fabrics break? _____
    d. Use the graph to complete the table below.

Table 10: **Tensile changes (elongation) of a polyamide fibre as a function of the magnitude of the tensile force**

F [N]	ELONGATION [%]
50	
	120
250	

4. What are the benefits of clothing made from polyamide fibres?

_____

_____

_____

5. List the areas where polyamide fibres are used.

_____

_____

Appendix 2: Worksheet solutions

STRETCHING OF POLYAMIDE FIBRES – solutions for the teacher

Watch the video on stretching polyamide (nylon) and answer the following questions.

1. Write down the main characteristics of polyamide fibres.

Solution: It's a man-made textile fibre, fine, extremely strong and more elastic than any natural fibre.

2. What is the relationship between nylon and polyamide?

Solution: Nylon is the brand name of the first man-made polyamide and is sometimes used as a synonym for polyamide.

3. Use the graph below to answer the questions.
   - **a.** Is the stretch of polyamide knitted fabric linear? YES / **NO**
   - **b.** Does Hooke's law apply to the stretching of polyamide knitted fabric? YES / **NO**
   - **c.** At what force does the polyamide knitted fabric break? **306N or 367N or 350N**
   - **d.** Use the graph to complete the table below.

Table 11: **Correct solutions to the problem**

F[N]	**ELONGATION [%]**
50	**93**
125	120
250	**150**

4. What are the benefits of clothing made from polyamide fibres?

Solution: good elasticity, wearing comfort, smoothness to the touch and wear resistance.

5. List the areas where polyamide fibres are used.

Solution: clothing textiles, sports textiles, protective textiles, bags, ropes, medical and industrial filters, and carpets.

Promotional educational material

Promotional educational materials play an important role in raising awareness and educating individuals on topics such as circularity, sustainable consumption and education for sustainable development. The following text shows four examples of such materials, dedicated to kindergartens or tailored for students in all three educational periods and for students in secondary school. The posters are designed to promote awareness among children, educators, teachers and parents on topics related to circular economy and sustainable consumption.

The first poster, "**How to reuse textiles in kindergarten**", is designed to show different creative ways to reuse old textiles in kindergarten. The four ideas, which can be opened with a QR code, show how children can use old clothes to create new bags, towels, toys, dolls and new clothes. This is meant to encourage educators, parents and children to be creative and inspire them to reuse materials instead of throwing them away.

The second poster, "**Responsible clothing management**", focuses on promoting the principles of circular economy and sustainable consumption. The poster illustrates the six principles of sustainability: rethink, refuse, reduce, reuse, repair, recycle. These guidelines aim to encourage individuals to rethink their clothing consumption, refuse unnecessary purchases, reduce the amount of clothing, to reuse, repair and recycle. It is aimed at students in the first and second educational periods.

The third poster, "**Textiles and circular economy**", provides key information on the importance of the circular economy, using textiles as an example. Using pictures and simple terms, children learn about the principles of recycling, reuse and waste reduction. The poster is suitable for students of the third educational period. It illustrates how each individual can contribute to a sustainable way of life through their actions and thus preserve the environment.

The fourth poster, "**How to extend the lifespan of clothes**", which presents the impact of the clothing industry on the environment, is aimed at secondary school students and promotes sustainable clothing management practices. The poster provides tips on how to take good care of clothes and how to extend their useful life. The aim is to promote responsible management of textiles.

Kindergarten

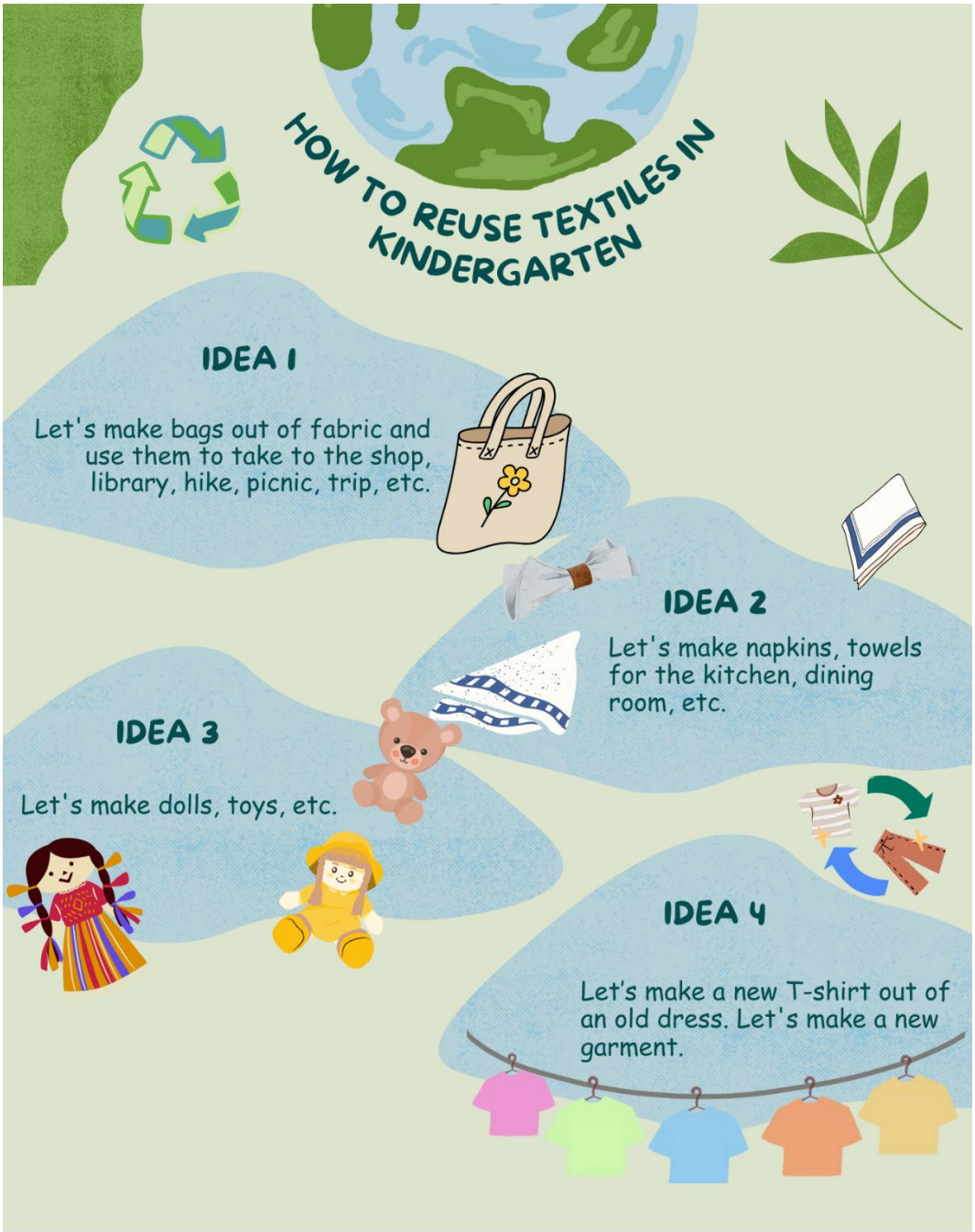


Figure 43: Poster How to reuse textiles in kindergarten

1st and 2nd educational period

Figure 44: Poster How can I save the world?

3rd educational period

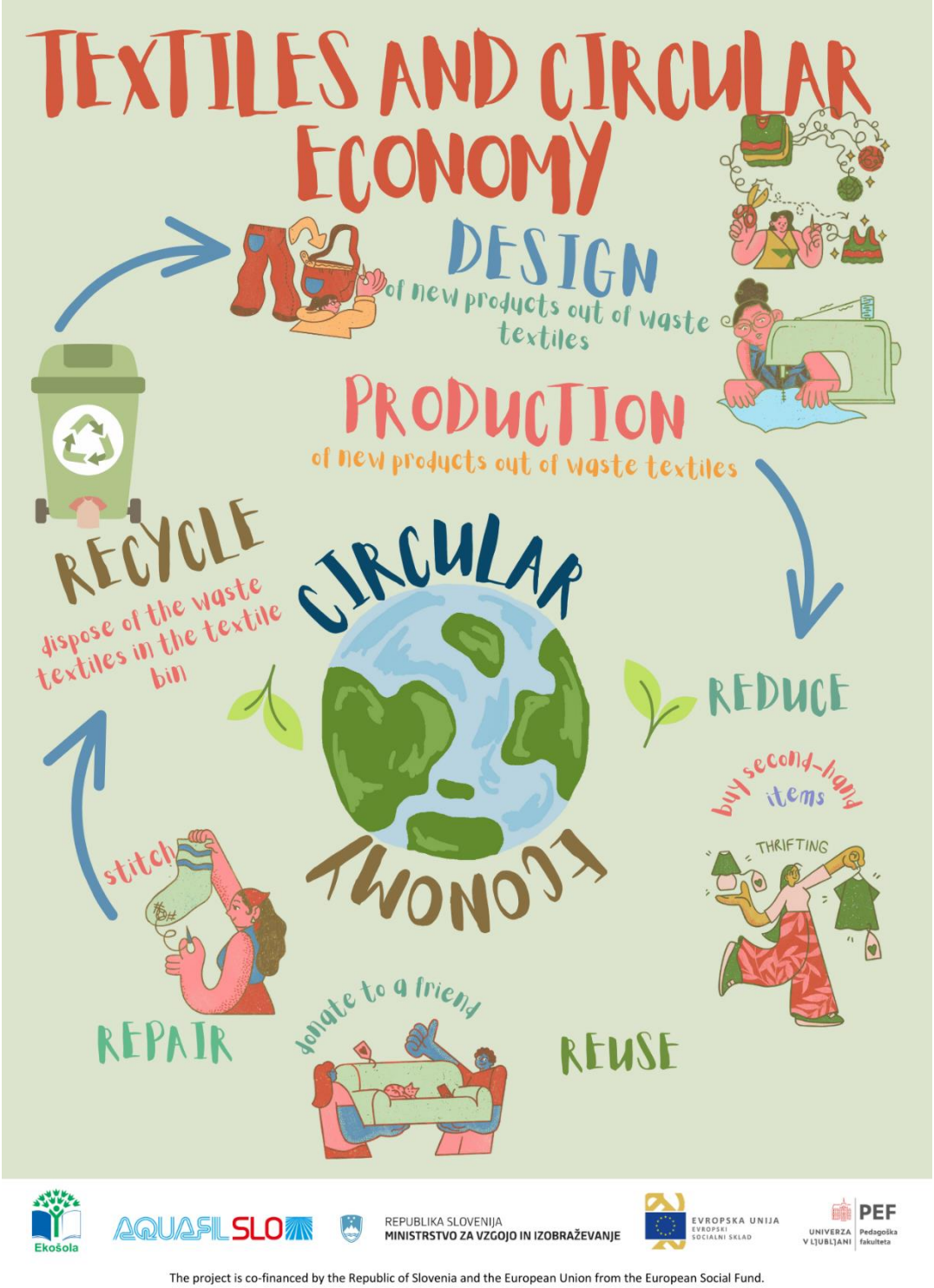


Figure 45: Poster textiles and circular economy

Secondary school

Figure 46: Poster How to extend the lifespan of clothes?

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Circular economy and textiles handbook

The handbook, which consists of 11 learning activities, aims to understand and explore the concepts of the circular economy and is tailored to the specific age groups and development needs of students – in kindergarten, at two levels of elementary school, and in secondary school. Lesson plans reflect the importance of sustainable practices and responsible consumption by teaching how to act more sustainably. It encourages creativity and innovation and responsible behaviour in line with the needs of our planet, so that we can lay the foundations for the future and build on sustainable practices and responsible consumption.