Plants growing on wastes? Classes scenario based on household wastes

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„Responsible consumption and production", „climatic action", „life below water" and „life on land" – these four issues are only few examples of the sustainable development goals [Sustainable Development – Knowledge Platform] (https://sustainabledevelopment.un.org). To achieve them, however, one should take into consideration another goal – this is namely „quality education". There is no doubt that the earlier the environmental education begins, the higher chances for building the society aware of the environmental issues. Many authors emphasize the need of promotion pro-environmental attitudes among children at the kindergarten and primary school level (Falkiewicz-Szult, 2014, Lelonek, 1984, Męczkowska and Rychterówna, 1923). It is very significant nowadays, while we are facing unmeasurable consumption and waste production which cannot be biodegraded in majority. The Statistical Office in Katowice (Poland) published in 2015 „Wskaźniki zrównoważonego rozwoju Polski" (Sustainable Development Indicators of Poland). Among other things, the authors analyzed data concerning waste management. Table 1 shows a few categories of waste management and production with data for the last year presented in the publication.

Waste management is crucial for environmental protection and conservation. Waste production utilizes energy and resources, thus improving the waste management technology, including recycling, should be a desired course. In 2015 the production of plastics and other similar polymers reached 58 mln tons in the European Union, Norway and Switzerland (circa 18% world production) (PlasticsEurope, 2016). In 2015 Poland took sixth place in the ranking of plastics demand in Europe (6.3%) (PlasticsEurope, 2016). The highest use of plastics in Europe concerns packaging and building materials (respectively: 39.9% and 19.7% in 2015) (PlasticsEurope, 2016). Despite the need of the waste recycling, people exhibit various attitudes toward waste sorting. The low level of awareness reflects in ignoring the rules of waste segregation in Poland (for example: putting different types of rubbish in wrong bins and containers, disposing of unsqueezed bottles), developing of wild garbage dumps or burning garbage to heat homes.

Category	Year of data	Value	Trend
Non-mineral waste generated per capita	2012	1883 kg	Fluctuations with increase
Municipal waste generated per capita	2013	297 kg	Decrease
Municipal waste treated by landfilling per capita	2013	157 kg	Decrease
Municipal waste collected selectively in relation to total municipal waste	2014	19.8%	Increase
Recycling of packaging waste	2012	41.4%	Fluctuations

Tab. 1. Data on the waste production and management published in „Wskaźniki zrównoważonego rozwoju Polski" (*Sustainable Development Indicators of Poland*) (2015).

Non-mineral waste: construction waste, soils, various mineral waste, dredged material. Municipal waste: mainly generated in the households. Source of data: Eurostat, GUS.

Wastes represent a great threat to ecosystems and organisms which inhabit them. Studies conducted in two forest stands near Ostrów Wielkopolski (Poland) proved that waste disposed in forest pose a great threat to life of invertebrates and small vertebrates (Kolenda et al., 2015). Among 254 collected pieces of rubbish 102 did not contain any animals, however 111 of them became graves for animals and there were alive animals in 76. Invertebrates outnumbered vertebrates, nonetheless dead rodents (4 species, 5 specimens) and shrews (2 species, 5 specimens) were found. Jambeck et al. (2015) estimated that 192 coastal countries produced 275 million metric tons of plastic and 4.8-12.7 million metric tons entered the ocean waters in 2010. These wastes are dangerous for the marine life. Probably the most popular example are sea turtles confusing plastic bags with jellyfish. Furthermore the plastic trash is commonly found in stomachs of birds, e.g. the Magellanic penguins (*Spheniscus magellanicus*) (Pinto et al., 2007). But what is even worse, Wilcox et al. (2015) estimate that till 2050, 99% of sea birds will „feed" on plastics. Plastic products do not degrade easily or they do not degrade at all and they lead to death of lots of birds nowadays. The mass production and disposing of plastics in environment induce changes in ecosystems – the nature tries to respond to a new factor. It can be seen in behavior of many animals. Hermit crabs (*Coenobita purpureus*) use plastic wastes the same way they use seashells – as shel-

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ters (http://okinawanaturephotography.com/). Birds use rubbish to decorate their nestes, e.g. the black kite (*Milvus migrans*) (Sergio et al., 2011). Moreover two species of solitary bees representing the genus *Megachille* use plastic materials to build their nests (Maclvor and Moore, 2013).

To reduce the amount of wastes on dumps and contribute to protection of the natural resources, we should convert and recover waste if it is possible. Such materials as paper, glass, plastics and metals can be recycled. Various biodegradable waste can be composed at large scale or in the households. Composting is a degradation of biodegradable products due to the activity of microorganisms in proper thermal, humidity and oxygen conditions. Compost may be used as a soil and fertilizer (Möller, 2016). However, one should remember that the properties of compost depend on the material which was composted (Möller, 2016, Prasad, 2013,). Biowaste generated in city may be called „urban organic wastes". It can be broken down into several categories, for example household biowaste, green waste from gardens or organic waste from food processing (Möller, 2016). Knowing the source of waste is important due to presence and amount of various chemical elements in them. To simplify, probably the most crucial are phosphorus and heavy metals. While phosphorus is playing a significant role in growth and development of plants, heavy metals are toxic to organisms (Möller, 2016). Due to numerous applications of compost which production is connected with chemical cycling and energy flow in nature, compost can be defined as renewable natural resource.

Recently, an idea of creating urban composters has emerged. Everybody would have access to these composters and the compost produced there would be used according to planned earlier purposes. The Social Initiative „I hand over waste" (Oddam Odpady) runs the campaign „Open composters" („Otwarte Kompostowniki") which aims to gather data about public, accessible for everyone urban composters. Furthermore the authors provide information about location of the open composters by showing them on a map (http://mapa.oddamodpady.pl/, access 25.02.2017).

It is estimated that until 2020 the mass of all types of waste per capita will reach 680 kg (Pawul and Soczyk, 2011).

Shaping pro-environmental attitudes in kids and youths by teachers requires long-term nurturing of students with paying attention to the educational content and ways of acquiring the ecological knowledge. Such knowledge should stimulate exploration and constant curiosity of the surrounding reality, thus it should also be applicable outside the school and in free time. (http://www.pdg.ug.edu.pl/studenci/edukacja_ekologiczna.pdf after Klus-Stańska, 2000). (Męczkowska and Rychterówna) already shared that opinion in 1923. The conclusion is obvious: the theory provided in the classroom is not enough to deal with waste sorting and recycling issues. There is a need to support the process of teaching with practical experiences to awaken the curiosity.

In the face of great anthropopression, here we suggest a classes scenario for the primary school students. The core curriculum, indeed, requires realization of lessons concerning waste management, but especially during the first level of education (I-III primary school classes). The school subject Nature which is realised in IV class of the primary school was given an aim „*Acceptance of the responsibility for the condition of the natural environment* (...)" which allows to remember students the significance and rules of waste management. Moreover it is possible to connect the waste management issues with at least two of the points which are meant to be realized during V-VIII classes of the primary school: „*VII. Ecology and environmental protection. The student: 9) presents renewable and non-renewable natural resources and suggests ways of rational management of these resources in compliance with points of the sustainable development*" and „*VIII. Threats to biodiversity. The student: 4) justifies the need of the biodiversity protection*". However, it is possible only when realization of the point VII. 9) will be based on the rational waste management in compliance with sustainable development. Otherwise it will be meaningless to find an educational aim on that school level which could be connected with waste issues. It seems to be logical to integrate the point VII. 9) with VIII. 4) from the point of view of threats which mass waste production poses to environment. Furthermore there is a suggestion in the core curriculum that realization of both sections (VII and VIII) as well as V and VI should be done in the last class of the primary school. This raises doubts about carrying out reliable lessons concerning such issues, when we take into consideration that there is so much material and so little time to teach and to prepare for the final exam of the VIII class. Here, provided by us school scenario may be used as a variety of an ordinary lesson or after-school activity.

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Scenario

Target group: 10-15 years old.
Form of activities: group work, individual work.
Methods: scientific, laboratory, verbal, project.
Time: at least 3 weeks (including two lesson units – 45 min).
Materials:

- Garbage collected by students in their households, according to the scenario.
- Garden soil (5-10 litre).
- Seeds of rapidly sprouting plants: bittercress, tomato, lettuce, fenugreek, radish.
- 20 pieces of 0.5 litre glass jars in reserve.
- 10 litre or 20 litre wastebags may be also helpful.

Aim: Due to analyzing the problem of waste mass production and management, the classes are meant to stimulate pro-environmental attitudes in students who will spread them further in future in the society. It is in agreement with expected effects of implementation of the project method (Stawiński, 2000).

Core curriculum

(new version which will take effect on 1.09.2017) (Dz.U. 2017 poz. 356):

Primary school, IV class, school subject: Nature.

Aims of education – general requirements

III. Shaping the attitudes upbringing.
7. Acceptance of the responsibility for the condition of the natural environment through:
1) proper behavior in the natural environment,
2) social responsibility for the condition of the neighbourhood,
3) the activities for the local environment,
5) conscious activities for natural environment protection and conservation.

Educational contents – detailed requirements

VII. The anthropogenic environment and the landscape near school. The student:
3) determines relationships between elements of the natural and anthropogenic environment.

Primary school, V-VIII classes, school subject: Biology.

Aims of education – general requirements.

II. Planning and conducting of observations and experiments; concluding. The student:
1) determines the research problem and hypotheses, plans and conducts simple, biological experiments, and documents observations;
2) determines conditions of the experiment, distinguishes control from experimental variants;
VI. The attitude toward nature and environment. The student:
1) explains the necessity of conservation;
2) presents an attitude full of respect toward him-/herself and alive organisms;

Educational contets – detailed requirements

VII. Ecology and environmental protection. The student:
9) presents renewable and non-renewable natural resources and suggests ways of rational management of these resources in compliance with points of **the sustainable development**.
VIII. Threats to biodiversity. The student :
4) justifies the need of the biodiversity protection.

Description of classes

1. Students are divided into four teams by the teacher.
2. Each team is given a task to collect one type of wastes in the households: I. Plastic products – plastic bags, packaging products, bottles, II. Paper – cartons, journals, III. Glass – jars, bottles (**unbroken**), IV. Biowaste (preferably food waste) – egg shells, peelings, green waste. Plastic and glass waste should be rinsed with water to avoid unpleasant odour and development of fungi.
3. After one week of collection students bring wastes to school and notice the diversity of wastes generated in the households. Basing on the observations of students, the teacher estimates with them the amount of wastes per capita, generated during one week and then during one year. The wastes can be measured with a tape measure to estimate the volume they occupy by comparing them mathematically to a cuboid, or by putting them in wastebags with known volume. The calculations are made by the teacher or students dependably of the educational level.
4. Students prepare the material: they count 200 seeds of the chosen plant and then pour them with water and leave for 15 min.
5. If there is insufficient amount of 0.5 litre glass jars, students will use prepared earlier jars. Prepare the experiment in well-lighted place. Each variant prepare in two repetitions:
   - Jar I. Fill it with the garden soil almost to the top.
   - Jar II. Cut and shred the plastic wastes to pieces. Place them on the bottom of the jar. Then coat it with a layer of the garden soil. Repeat the pattern two more times (in total six layers).
   - Jar III. Similar to Jar II, however replace the plastic wastes with biowastes.
   - Jar IV. Similar to Jar II, however replace the plastic wastes with paper.
   - Jar V. Cut and shred the plastic wastes to pieces. Fill the jar with them almost to the top.
6. The teacher asks students to point the control variant (Jar I) and experimental variants (Jars II-V). Students pour each jar with the same volume of water – 100 millilitres. They sow 20 seeds on the top layer of each jar (they use seeds poured with water in point 4.).
7. Students observe germination and growth of plants. Whenever needed, they water the plants to enalble germination. Students take notes how many plants germinated and how many of them survived after two weeks. It is possible to measure the length of seedlings and roots.After two weeks the students remove the content from all jars and evaluate the state of wastes. The observations of the state of glass degradation can be performed as evaluation of the state of glass jars. All material must be gently removed from jars if the shoots and roots of seedlings are planned to be measured. Otherwise they may be damaged. Finally, the students state their conclusions.
8. Results and conclusions of the experiment can be presented in a form of a note in the notebook, classroom exhibition, photo reportage, blog in the internet and others, as suggested in Pilichowski and Tokarska-Osyczka (2016).

Examples of the research problems formulated by the students:

- Influence of soil organisms for decomposition of waste.
- Influence of water for decomposition of waste.
- Influence of waste for a plant growing.

Examples of the questions formulated by the students:

- Is the glass decomposed due to the activity of water and soil microorganisms?
- Is the plastic decomposed due to the activity of water and soil microorganisms?
- Are the paper waste decomposed due to the activity of water and soil microorganisms?
- Are the kitchen biowaste decomposed due to the activity of water and soil microorganisms?
- Does the plastic provide conditions for life of plants?
- Does the soil enriched with kitchen garbage provide better conditions for plant development?* (in order to obtain more reliable results we recommend to cultivate the plants longer than two weeks).

Examples of the hypotheses which can be formulated by the students:

- Glass is water resistant.
- The plants are not able to grow on a substrate solely consisting of the plastic.
- Plastic is resistant to soil microorganisms.
- Kitchen waste can be composted.

Examples of the conclusions formulated by the students:

- Plastic does not dissolve and degrade in water (Jar V).
- The plastic is not biodegradable. Mechanical shredding of the plastic wastes by soil organisms and plant roots can occur in nature (Jar II).
- The plastic does not provide nutrients for plants, unless it is contaminated with organic and inorganic matter (for example: food leftovers). However, these are limited resources (Jar V).

- Waste paper is decomposed in the soil as a result of activity of microorganisms and invertebrates (Jar IV).
- Bio waste can be successfully composted and used as a fertilizer after processing or substrate for sowing plants (Jar III). The teacher should consequently explain that the process of degradation of organic matter takes several weeks to several years, depending on the type of material and processing conditions.
- Glass is not degraded by water and soil microorganisms.
- Plants need substrate to root in and uptake minerals, and water to develop and grow correctly.
- Non-biodegradable wastes, such as glass and plastic, discarded into the environment pose a threat to the fauna (look at the source text). Thus, it is essential to throw waste in accordance with the principles of segregation and storage and with respect to the surroundings, environment and nature.

If the lengths of shoots and roots were measured, they can be compared between control and experimental variants. Calculate the average length of shoots and roots of both repetitions. If the repetition failed (low level of germination, drying the variant), discard it in the analysis.

Appendix I. Material for the student

Human produces unimaginable amount of waste that can pollute and damage the environment. Apparently, it may not be a dangerous plastic bag which becomes a great threat to sea turtles confusing it with a jellyfish and after swallowing the bag they suffocate and die. Waste disposed into the environment can become a death trap for many small animals, e.g. insects, arachnids, small rodents and shrews. Unfortunately, plastic and other materials are difficulty or non-degradable in the environment, contaminating them for years. Similarly, glass cannot be biodegraded. However, there are types of waste that decompose in the environment. These is green waste we produce practically every day in the households, for example: peels from vegetables, grass mowed in a front of the house or dry leaves falling from the trees in autumn. There are other waste which we can manage: eggshells, old fruit etc. If there is enough space, one might think of building a small composter, where all waste could be converted into a high-quality substrate for plants or fertilizer. Another interesting solution are urban composters with access for everyone. Maybe in your city it would be possible to build it?

Fig. 1. Wild wastedumps pose a risk to animals and plants, especially when they are the source of chemical contamination. Moreover bottles, plastic bags and all containers can be deadly traps for small fauna.

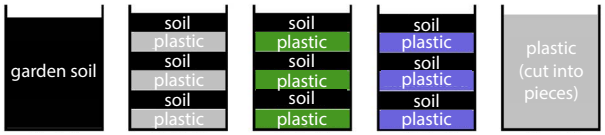


Fig. 2. The experimental schema. Five jars in five variants (control and four research variants).

Run an experiment in accordance with instructions provided by the teacher:

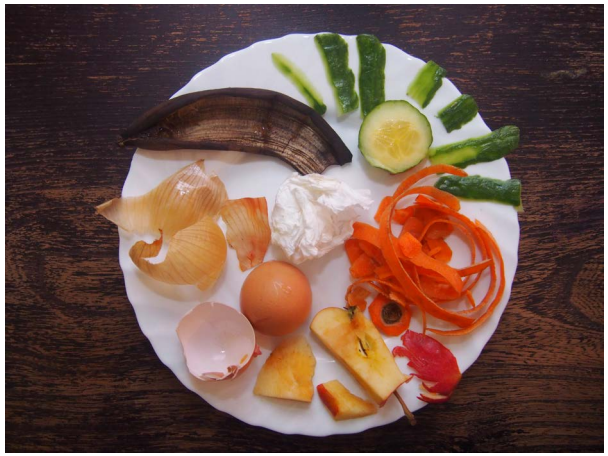


Fig. 3. An example of bio waste which may be material for composting.

Fig. 4. Preparing jar V filled with plastic and similar polymers. 1. Collect garbage, wash it in water. 2. Cut into small pieces. 3. Fill the jar tightly with them.

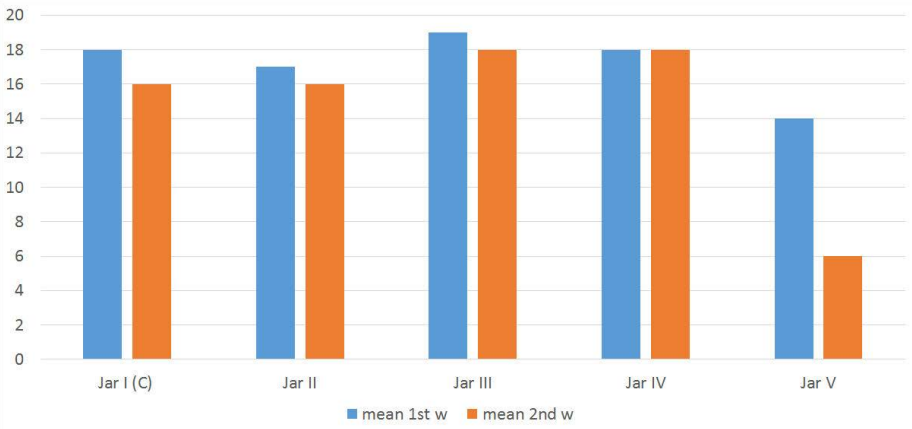
Appendix II. Observation card.

1. Before setting the experiment formulate:
   - The research problems.
   - The research questions.
   - The research hypotheses.
2. After finishing the experiment formulate conclusions.
3. Complete the table by writing the number of germinating seeds after two weeks of observation.

Number of germinating seeds		
Replication	I	II
Jar I		
Jar II		
Jar III		
Jar IV		
Jar V		

4. Complete the table by writing the number of living plants after first and second week of observation. Calculate the average number of plants of two repetitions of the same variant (jars I–V). Show the results on the bar graph prepared in Excel/OpenOffice Calc (see example).

Number of alive plants		
After	I week	II week
Jar I		
Jar II		
Jar III		
Jar IV		
Jar V		



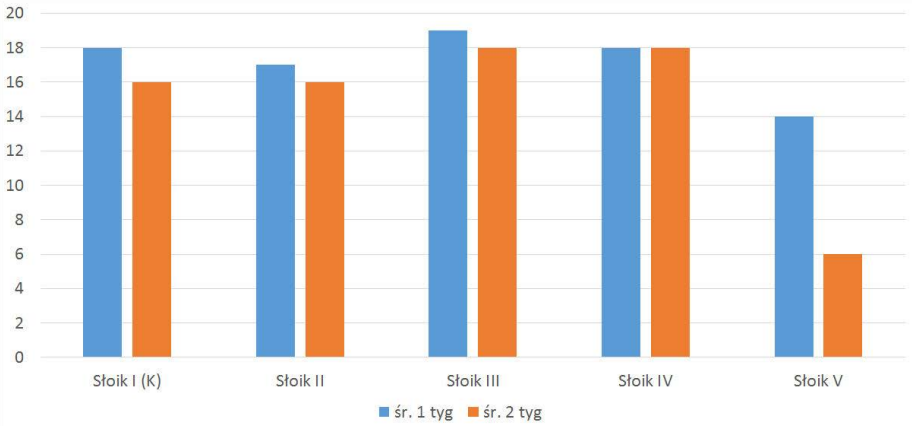


Fig. 5. An example of a bar graph showing a comparison of mean values of alive plants after first and second week of the experiment

Jar I (C) – the control variant.,

mean 1st w – the mean value of the number of living plants after the first week of experiment,

mean 2nd w – the mean value after two weeks of experiment.

5. Take photographs of the material used in five research variants (jars I-V) in the first day of observation before you put the material in the jars and in the last day after you remove it from the jars. Compare the photos (state of the content of the jar I in the first day with the content in the jar I in 14th day etc.). Note your observations. Answer the question: Whether and in which jar the waste decomposition occurred? (see example)

Appendix III. Table of measurements of the length of sprouts and roots.

Task 1. Measure the length of sprouts and roots. Numbers 1-20 represent plants from jars I-V.
Task 2. Calculate the average length of shoots and roots of the two repetitions. If the repetition was failed (low level of germination of plants, dried variant), discard it in the analysis.

plant name: ……..											
the numer of jar		I	II	III	IV	V	I	II	III	IV	V
repetitions		I					II				
the length of sprouts [mm]	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
	15										
	16										
	17										
	18										
	19										
	20										
	average										

the length of roots [mm]	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
	14										
	15										
	16										
	17										
	18										
	19										
	20										
	average										

Links

- https://sustainabledevelopment.un.org/?menu=1300 (access 22.02.2017)
- http://okinawanaturephotography.com/tag/hermit-crabs-in-plastic/ (access 22.02.2017)
- http://oddamodpady.pl/gdzie-sa-otwarte-kompostowniki/ (access 25.02.2017)

