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MODELS OF ROBOTS THAT COLLECT PET, CAN AND TETRA PACK, THEY WERE MADE WITH URBAN SOLID WASTE AND PROPOSE BY STUDENTS OF TECHNICAL CAREER.

RODRÍGUEZ-ANGELES, M.G[1].

[1] CENTER FOR SCIENTIFIC AND TECHNOLOGICAL STUDIES NO. 11 "WILFRIDO MASSIEU", CHEMISTRY, NATIONAL POLYTECHNIC INSTITUTE, MEXICO CITY, MEXICO.
EMAIL: [1]mgrodrigueza@ipn.mx, magraawmp_1999@yahoo.com.mx
ORCHID ID: [1]https://orcid.org/0000-0002-6554-0046

ABSTRACT:
The National Polytechnic Institute (IPN) of Mexico is a leading institution in technological education and sustainable education in its community is part of its institutional development plan. The objectives were: 1) To design a robot to collect PET, Tetra pack and can in the school, 2) to induce students to research. The active didactic strategy of project-based learning (PBL) was applied to a group of 45 students of the Industrial Processes Technical career. The group was divided into teams to propose models of urban solid waste collection robots, them were built with recycled materials. This activity induces students to manage information, creative and to be interested in research. The students proposed 4 models, which can be brought to reality. Sustainability considers the environmental, social and economic factors. In the new generations, sustainable education must be strengthened, and actions must be carried out to care for the environment. SIP20241998 "Wili robot, technology in support of environmental care" and 20251232 "Design of a robot that collects PET, can and Tetra pack, technology in support of environmental care in CECYT 11 sustainable school, IPN.
Keywords: Sustainability, urban solid waste, robot, project-based learning, environment

1) INTRODUCTION:

The lifestyle of modern man, industrial and technological development have caused a negative impact on the environment, proof of this is climate change and the pollution of water, land and air. Environmental deterioration and the excessive use of natural resources without awareness, worried various nations, so in the report made for the United Nations (UN) by Gro Harlem Broundtland, Prime Minister of Norway in 1987, in collaboration with an environmental commission made up of scientists and experts from 21 countries, the concerns and actions issued to stop environmental damage were raised. their social, political and economic impact and restore the balance between these three factors.
The document is a guide to policies between countries to help the environment and it was indicated that sustainable development is the development that meets the needs of the present without compromising the needs of future generations, even with the advance of technology, industry, the use of natural resources, the activity of society and the capacity of the environment to overcome human activity that is moving towards progress. change and continuous improvement **[1].** In addition, man must take care of the various species of plants and animals that cohabit on earth, since there is more and more extinction of them **[2].**
Sustainability is "meeting the needs of the present without compromising the needs of future generations." On the other hand, sustainability is therefore a complex process that involves the environment, society and economy that must be maintained in a balanced way over time. These two terms are used as synonyms very frequently **[3], [4], [5].**
Currently we are experiencing the consequences of not taking care of the environment, so it is necessary to emphasize raising awareness among the population, to carry out actions aimed at taking care of the planet and reversing the damage that man has caused to the environment with the pollution of water, air and land.
The contamination of the earth has been caused gradually by the increase in population, the emergence of industries, the lack of environmental education in the population that throws garbage at any time and place. This causes the contamination and depletion of the natural resources necessary for human life and activity. In some countries, waste disposal is not regulated, while others are controlled by environmental quality standards to reduce the negative impact on the environment **[6].** The terms waste and solid waste are currently used as synonyms from a technical and legal point of view, but they are different because waste have not added monetary value or can not be reused in industrial processes, whereas waste is reusable or inert and can be used more than once [**7**].

Pollution is caused by substances or elements that damage the environment and decrease the quality of soil, air or water and consequently of the different manifestations of life, animals or plants.

The health of humans, animals, plants and the ecosystem in general is damaged by pollution, in addition to contributing to climate change, soil degradation, changing the water quality of rivers, lakes and the sea.

The objects and polluting substances are diverse and of different origins, such as industrial waste, toxic gases, plastics, cans, cardboard, paper, chemical products, glass, Tetra pack, cloths, shoes, PET, among others **[8], [9].**

Waste may be solid, liquid or gas. Urban solid waste (MSW) is produced by man during his activity in cities, in spaces such as schools, homes, shops, industries and public spaces. They are classified according to their composition and dangerousness: non-hazardous and dangerous, special handling and radioactive. The prompt management of this waste is necessary to reduce pollution and because it can be a health problem as it is a focus of harmful fauna such as rats, cockroaches and flies that transmit diseases, if action is not taken its production will increase by 70% in 2050. MSW can also be classified as organic and inorganic and non-recoverable when they have no value and recoverable those that can be reused or recycled and have a monetary value such as paper, metal, wood, plastic and glass**.** In the recoverable MSWs, there are PET, cans and Tetra packs, which are most frequently found in schools **[10], [11].**

The man knowledge, the development of technology and the overuse of natural resources have caused damage to the planet and led to environmental pollution.

Technology may be a powerful tool for reversing damage, as evidenced by the design and construction of robots that help clean up the sea or streets by collecting trash or MSW.

The Czech writer Karel Capek in 1921 used the term robot which comes from the Czech words "robota" meaning "compulsory work" and "robotnik" meaning servant. The "Unimates" were the first industrial robots created between the 50's and 60's of the last century by Joe Engelberger, considered the father of robotics. In the 80's its development and use was greater. The word robotics was first used in 1942 and refers to the science that studies and researches the design, construction, operation and maintenance of robots. This requires integrating knowledge of computing, mathematics, electronics, physics, electricity, mechanics, chemistry, biology, and neurosciences **[12].**

Robots are currently used in construction, pipeline examination, in restaurants as waiters, combat, in health to perform surgeries or as part of prostheses to give a better quality of life to man or animals, also detection of gases such as methane, CO_2, measuring temperature and humidity in agricultural soils, just to mention a few examples **[13].**

The development of a research project for the design and construction of a robot that collects MSW such as PET, aluminum can and Tetra pack, represents a didactic strategy to facilitate teaching and interest students in research.

Professor Haward Barrows in Canada in the 1960s, wanted to implement a method of active learning with his students, the project-based learning (PBL), that it was different from traditional education that was only transmission of knowledge from the teacher to the student who memorized the information **[14].**

Among the active didactic strategies for student learning in the classroom and other environments are project-based learning (PBL), problem-based learning, gamification, challenge-based learning, flipped classroom, collaborative work, case study, debate, science-based method, technology, engineering, art and mathematics (STEAM). PBL can be a didactic strategy to interest and induce students to research and collaborative and active work **[15].**

A didactic strategy is a systematized procedure with actions to facilitate the teaching-learning process, to achieve this, various resources and means are used that allow the student to build meaningful learning **[16], [17]**.

The student is the one who carries out active work in PBL, to solve real and complex problems of daily life and their environment. Thus, students develop skills by carrying out autonomous learning and collaborative teamwork, in an interdisciplinary way with teachers and students from the same or different technical careers to apply what they have learned to solve current problems such as environmental pollution and sustainability **[18].**

Through PBL, the student designs and builds a final product that solves a real problem. To do this, they must previously carry out observation, analysis and integrate knowledge from their personal life experience, from the classroom, from laboratories and workshops that they take throughout their academic and technical preparation at school, making use of strategies and the research method, in a joint student-teacher work in an active way, which is socialized **[19].**

PBL takes elements from constructivism and the works of Vygotsky, Piaget, and Bruner, considering the social and continuous nature of learning, as well as the mental models that lead the individual to knowledge **[20].**

When developing research, students perform complex tasks and develop superior mental capacities such as information management through search, critical analysis and synthesis, critical and systematic thinking is promoted, and commitment and responsibility are strengthened when working in teams and individually [**21].**

PBL allows us to contribute to proposing solutions to the current problem, which is the pollution due to human activity of land, water and air due to the production and storage of MSW that in the long or short time affect humanity and can lead to the extinction of species**.**

Project-based learning (PBL) is an active didactic strategy that allows the student to actively participate in the construction of their learning.

2) METHODOLOGY:

The application of PBL was carried out in this research in a group of 45 students who were in the second level of bachelor degree of the Center for Scientific and Technological Studies No. 11 "Wilfrido Massieu" (CECYT11), of the Process Industrials Technician (TPI) career, they were organized into 4 collaborative work teams, in the subject of Chemistry in which they review the periodic table and all the metals that can serve as material to build a robot that helps reverse pollution because some times they do not find application in their technical career, so it is necessary to apply didactic strategies such as PBL and design activities that motivate and interest them and in which they integrate knowledge, previous and new, as well as theoretical and practical knowledge of the technical career they are studying.

The problem posed to the students was that currently, the environment is highly polluted, in the air, water and land, so it is necessary to reverse the damage that man has caused with his daily, industrial and domestic activity. The teams were asked to carry out documentary research with references in APA format on the following topics: 1) They carried out research on the origin and classification of urban solid waste and 2) Proposal for the design and construction of a robot with recycling material. In addition, the information integrated in a Word document, material for oral presentation in Power point and the model of the robot's proposal was requested.

In the process of decomposing garbage, various chemical reactions take place that release heat, pollute the environment and can cause damage to the health of humans, plants and animals.

In the Process Industriales career to which the students belonged, environmental awareness and education are promoted, and they are given tools for the care of the environment, avoiding the pollution of the planet, for this reason they were asked to investigate the classification of urban solid waste, recoverable and non-recoverable. The students can design robotic warmth for collect wasted.

The students also carried out previous research on the robots that already exist in other countries to clean the environment and the other uses to make a design proposal for the Wili robot, which could be in a scheme or built with useful recycled materials, to reduce cost and pollution. They had to propose a robot model to present at the end, which had to be evaluated following a rubric, feedback and validated by the teacher, to finally issue a conclusion.

Regarding the construction of the robot, according to the knowledge of the students and what they researched, these are the technical and environmental characteristics that should be considered in the design of a robot:

- Size and shape that allow it to move in addition to its functionality.
- Its weight must be adequate to be able to move even with MSW and to be stable.
- Propulsion system selected to move, whether wheels, tracks that will depend on the terrain in which the robot is going to work.
- The sensors must identify and distinguish recoverable waste.
- Mechanical arm or suction system to collect recoverable waste and deposit it in a container.
- The control system must allow the pre-established route to be carried out.
- Battery for independent power supply that allows the robot to work for a long time without recharging.
- Communication for operation by remote control.
- The operating environment, whether it is on the street, school, industry, beach or forest.
- The type of waste to be collected and the weight.
- Energy efficiency in its operation, so that the energy required to reduce costs is minimal, may be with photocells.
- That robot is safe for people, animals and the environment.

3. RESULTS:

The PBL didactic strategy, applied to students to induce research and make meaningful the learning of the periodic table and different metal.

The students were asked to carry out documentary research on solid waste, its origin and classification, so that due to its origin it can be organic or inorganic. Organic waste is biodegradable like the remains of food, plants or animals subjected to the composting process, through which it is it makes organic fertilizer and the nutrients they contain are used, reducing the amount of organic matter that goes to landfills.

Inorganic waste is diverse, such as cardboard, paper, plastic, glass, metals such as aluminum from cans, these materials can be recycled. Waste is also classified as recoverable and non-recoverable. Recoverable products can be recycled, reused or converted into useful resources, such as paper, glass, plastic, metal and cardboard, among others. Non-recoverable waste cannot be easily recycled or reused, such as some types of non-recyclable plastics, waste that is toxic to health and the environment. It is necessary to properly manage both types of waste to minimize the environmental impact **[11].**

Others important waste are containers and packaging for various products such as food, beverages, cosmetics and cleaning products. Electronic waste that is no longer functional and that may contain precious metals, toxic substances that harm the environment and human health. Construction and demolition waste such as wood, bricks, concrete and metals should also be considered, as well as household waste generated in homes, including personal hygiene products and food. Commercial waste generated in stores, restaurants, offices and hotels also requires

attention, such as cooking oil from restaurants. Chemical waste is produced in industries, among other materials that are harmful to health. Public and municipal services generate waste from public roads, street and garden cleaning, as well as infrastructure maintenance.

Asi como para el medio ambiente

Hazardous waste represents a risk to human and animal health as well as for the environment because it can be corrosive, reactive, explosive, toxic, flammable or biological-infectious and requires special treatment and disposal. Among them are chemicals used in schools, industries and hospitals, batteries, used oils, expired medicines and electronic waste, mainly.

Regarding the design of the waste collection robot , the students made the following considerations for its functionality and effectiveness in the collection of selected recoverable waste: PET, Tetra pack and can.

The structure must be robust, so the resistance of the materials and the robot itself must be considered, as well as its stability and mobility during its operation in different weather conditions and uneven terrain.

The figure 1 shows the model of the Wili robot, proposed by the students. They were made whit recycle material. Models of robots for collect PET, aluminum can and Tetra pack.

The model of robot A opens the hatch to collect MSW an the B model has a brush that collects all kinds of garbage and a robotic arm to select it.

Figure 1 (a) Robot with robotic arm and gate.

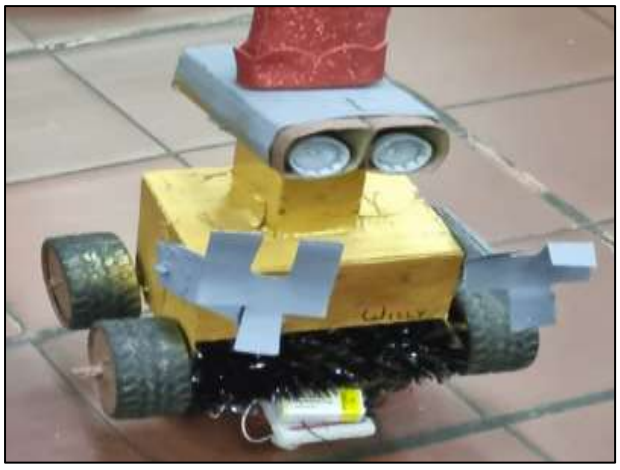

Figure 1 (b) Robot with robotic arm and brush

When the students researched about the countries that produce robots in order to clean the environment, they found that some of them are Japan, Norway, the Netherlands, Germany, China, Norway, Sweden, among others. Table 1 shows some examples of robots its use and operation.

Table 1. Use and operation of robots different.

Use	Country
Collect waste in parks and squares.	France
Cleaning of rivers and ports.	Australia
Clean up oil spills at sea.	Japan
Pick up trash in the streets.	Finlandia
Determining soil temperature and humidity	Spain, Brazil

Surgery	China, United States
Prosthesis	Japan

The table shows the use of robots and the country where they are built.
Source: Own elaboration (2025).

The presentation of the work as a whole and the robot model was done in the Classroom Project fair where external teachers evaluated the models whit a rubric and their writing.
The next step was to move the robot model with sensors, wheels, motors, batteries and other components. For this the multidisciplinary work of students from other careers such as electronics was needed, using components such as those shown in figure 2.

Figure 2 Electronic components for robot mobility.

4. DISCUSSION:

MSW management is important to protect the health of humans, animals, plants and the environment, impacting the quality of life of the population and ecosystems. A commitment of today's generations is to take care of natural resources, to use them efficiently and sustainably to help reduce their negative impact due to depletion, when they are used in the cycle of producing, consuming and sometimes half consuming, to finally discard. The way to avoid this is by closing production cycles in which the dependence of industrial production on natural resources is reduced and waste is minimized, this is an economic model known as circular economy **[22, 23].**
The IPN promotes the comprehensive training of professionals who actively participate in research, science, technology, culture and in the resolution of the country social problems, applying their knowledge, skills, attitudes and values, to contribute to the scientific and technological development of Mexico and the world, developing cutting-edge knowledge through research depending on the technical career from the students, and the results of which they socialized and shared whit others students.
The Institute develops and strengthens soft skills in students, including: the use of ICTs, collaborative work in work teams and simultaneously their capacity for analysis, critical judgment, management and synthesis of information, so that they learn to express themselves orally and in writing, to make decisions, exercise leadership and project-based learning. PBL allows students to interact in different face-to-face or virtual learning environments, so that they achieve these capacities and the investigative skill, necessary for life, profession and society **[24], [25].**
PBL is an active research strategy that allows students to learn, observe, innovate, reflect, analyze, propose, and work collaboratively, thus preparing for life and the profession **[15], [19].**
The PBL has advantages as a didactic strategy to be used with bachelor degree students from CECYT11, IPN:

- Active learning because students participate in the learning process, by carrying out activities that promote critical thinking, their capacity for reflection and analysis, by applying their knowledge to solve a problem.
- Previous knowledge is integrated with new knowledge, to carry out tasks, make proposals and actively work and interact with classmates and teachers. It is applied in a practical way to solve a problem, through a research project, leading the student to meaningful learning **[26].**
- In PBL, the students evaluated in each team proposal as a group, among various possibilities that were argued and discarded, through analysis and critical thinking, skills that were strengthened.
- The students carried out information management, by searching for it, selecting the sources of information, making summaries and integrating it all.
- Collaborative teamwork was strengthened, as were the different forms of oral and written communication and using tools such as information and communication techniques (ICT), which are important for professional training in engineering **[21].**

The disadvantages of PBL, we can mention:

- Its development and evaluation required more time, to solve the problem through research, make proposals and develop them.
- The evaluation was complex, more time and organization were needed, in this case a rubric was applied for the written documents, power point, the proposal of the model and greater organization in the development of the

work.

- In addition, economic, technological and material resources are needed, these can be new or recycled and depending on this will be the cost to physically build the Wili robot.

Project-based research at the technical bachelor degree is a teaching strategy throughout a course which requires knowledge and application of the scientific method, to carry out work in a planned and orderly manner, this will give advantages to the student when they advance in their studies and go to the professional or university level **[27]**.

In this work, research was promoted among students, to induce and motivate them to make proposals in which they apply and integrate their technical knowledge, to reverse pollution as one of the problems that currently affect Mexico and various countries.

Knowledge of the different MSW will make their management more efficient and sustainable and minimize their negative impact. In Mexico, the Ministry of the Environment and Natural Resources (SEMARNAT), in its regulatory function of the management of MSW, indicates that its disposal must be comprehensive, aimed at reducing its generation, reduction, economic valuation and disposal, in addition to carrying out education, training and communication strategies that contribute to the sustainable management of waste. The population, schools, companies, and various organizations that promote and encourage the recycling, reuse, or reincorporation of this waste must participate in these actions **[10], [28], [29].**

As for the technology for the construction of a robot, the students found that it has several advantages, considering the safety it provides and its efficiency, in the different professional fields, as a support to man in his activity, on the other hand, it also has disadvantages due to its cost. The appropriate design for waste management must achieve the desired impact on the environment to find a balance between the use of technology and the care of the planet **[12].**

5. CONCLUSIONS:

The APB allowed students to develop the ability to learn autonomously and collaborative work teams for the resolution of real problems, and to facilitate meaningful learning, where the integration of theoretical and practical knowledge is required, preparing students for life and profession, while strengthening their interest in research, reflection, critical thinking, their ability to communicate and use technology.

The participation of the students in a project where they can significantly apply their knowledge to solve a current problem such as the project for the design of a robot that collects, separates and classifies MSW, reduces pollution and its impact on the environment, motivated them to learn, and also represents a significant advance in the promotion and strengthening of more sustainable practices in waste management.

Robots represent a good option to optimize and speed up the garbage collection process, thus reducing the amount of waste that would end up in landfills or incinerators and consequently pollute the environment. On the other hand, by integrating knowledge of the different types of waste and technology in the construction of robots, plastic, glass, paper and metal can be separated, facilitating their recycling and reuse.

The conclusion of the students regarding this activity is that it strengthened the education and environmental and sustainable awareness that the career provides them, in order to carry out actions to avoid generating garbage and to recycle it when possible, since in this way pollution is reduced and it helps to reverse the damage that man has caused to the planet.

The PBL didactic strategy allowed the students to work collaboratively, strengthened their technical knowledge of the career, led them to manage the information consulted in various sources, to communicate in writing, to make use of ICT to make a proposal after analyzing and reflecting on the care of the environment. In addition, they found an application to periodic table.

In this way, the IPN promotes and induces students to carry out research, to be creative and innovative professionals in the field of science and technology.

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8) Data Availability: The data that supports the findings of this study are available in this paper.

9) Conflict of interest: The author declares that there is no conflict of interest**.**

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