Implementing POGIL approach in science education. A low-cost alternative to the chemical experiments recommended in the Polish core curriculum at ISCED 2 level

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INTRODUCTION

The results of Polish exams and research findings (e.g. *Laboratory of Thinking*) [1,2] indicate, that Polish students have difficulties with gaining key competences in science subjects, especially these concerning scientific method and laboratory procedures. **In our opinion, redefinition of the way chemical compulsory experiments are carried out in lower secondary schools (Polish: *gimnazjum*) should be undertaken.** The current list of laboratory experiments is linked to the new core curriculum for science education, introduced in 2008 [3]. The new curriculum emphasizes the importance of students' individual laboratory work in learning chemistry and the use of scientific methods to design and conduct chemical experiments especially using products from everyday life. Although the list of recommended experiments gives teachers the freedom to choose reagents and procedures which suit them best, this recommendations might be misinterpreted by using conventional and difficult experimental procedures. We believe that the development of simple, student-centered lab procedures for chemistry is the only way to improve effectiveness of students' learning process and to increase their positive attitude toward science subjects.

METHODOLOGY

Our laboratory activities were prepared in accordance with the **Process-Oriented Guided-Inquiry Learning method (POGIL)** [4] to encourage a deeper understanding of the labs' material, higher motivation and better development of higher-order thinking skills, such as critical thinking, problem solving and cooperation. The experiments suggested in this work are adapted versions of the ones successfully applied elsewhere [5]. Our proposal is based upon the use of inexpensive supplies and simple experimental techniques. The experimental procedures are designed to be easily performed by students, particularly, at schools with meager lab equipment and/or lacking typical reagents. We present here sample activities, which can easily fulfill curricular requirements, enhance student's abilities to design and conduct chemical experiments, and engage them in the learning process.

What's POGIL?

POGIL is a **student-centered** instructional strategy, based on **constructivist pedagogy**, developed by chemical educators in the late 1990s [4].

Process – Oriented (utilizes **Learning Cycle paradigm**)

Exploration —(inductive)→ Concept invention (term introduction) —(deductive)→ Application

Guided Inquiry (activities are constructed to introduce topics and encourage exploration)

Conventional Pedagogy

- Teaching is telling
- Knowledge is facts
- Learning is recall

Constructivist Pedagogy

- Teaching is enabling
- Knowledge is understanding
- Learning is active construction of subject matter

BASIC RULES

- Students work in small groups (3-4), often playing assigned **roles**.
- Students work on the specially designed **POGIL activities** during class time.
- Learning cycle parallels scientific method.
- The teacher serves as a **facilitator** of students' learning.
- Students **construct knowledge** based on their prior experiences.
- Students teach/discuss/learn from other students.

STUDENTS GO THROUGH SEVERAL STEPS:

Model introduction → Reviewing the Model (simple questions) → Model exploration (concept invention) → Application of the discovered concepts (problem solving, critical thinking questions) → Summarizing the discovered concepts (lab reports, oral reports)

STUDENTS' ROLES

- **MANAGER** - manages the group, ensures that the assigned tasks are being accomplished on time; the instructor responds only to questions from the manager
- **RECORDER** – records important observations, insights, conclusions
- **TECHNICIAN** - performs all technical operations for the group
- **PRESENTER** - presents oral reports to the class

SUMMARY

● POGIL is practically unknown in Poland but worth consideration as one of inquiry based teaching (IBSE) methods. ● It can be successfully applied at ISCED 2 level.

● Most of recommended curricular experiments can be converted into POGIL activities.

THE AIMS

- Redefinition of the way chemical compulsory experiments are carried out in lower secondary schools in Poland
- Preparation of curricular experiments for ISCED 2 level using Process-Oriented Guided-Inquiry Learning (POGIL) method
- Presentation of low-cost, easy to perform by students alternatives to the experiments recommended in the chemistry core curriculum

ACTIVITY 1

MODEL – detecting carbon dioxide in the air

Pre-requisite knowledge: air composition
Chemicals: 3-5ml of lime water, air
Equipment: test-tube, syringe, tubing
Procedure: The teacher shows an experiment in which air from a syringe is injected into the test-tube containing the clear solution of lime water.

All students discuss with teacher's guidance the following questions:

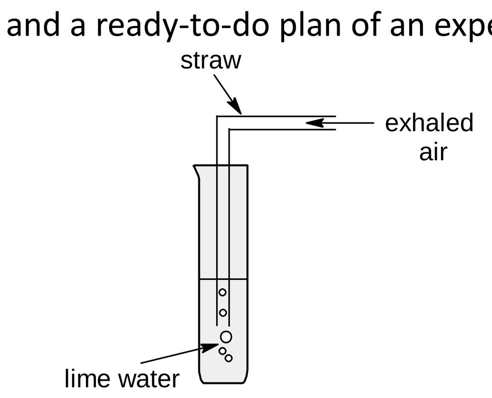
1. What happens with lime water solution when air is injected into the test-tube?
2. What is a cause of lime water turning cloudy?

After discussion, the teacher should ask simple questions to ensure that all students understand what is a lime water and precipitate, what reaction caused lime water to turn cloudy and what is a calcium carbonate.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3\downarrow + H_2O$$

PROBLEM – detecting carbon dioxide in the exhaled breath

Introduction: short analysis of the text about respiration and its products
Chemicals: 3-5ml of lime water, exhaled air
Equipment: test-tube, drinking straw
Problem: The teacher asks students how to detect carbon dioxide in the exhaled air using lime water.
Procedure: Students discuss in small groups about setting up above mentioned experiment in which a test-tube containing lime water will be exposed to the exhaled air. They should come up with a hypothesis and a ready-to-do plan of an experiment.



After conducting the experiment, students discuss in their teams following **Critical thinking questions:**

1. What happens with lime water solution, when exhaled air is blown into the test-tube?
2. What is the evidence that exhaled air contains carbon dioxide? What reaction occurs in the solution?

Then, short oral reports are presented to the class and students can compare their results.

ACTIVITY 2

MODEL – red cabbage juice as an acid-base indicator

Pre-requisite knowledge: properties of acids and bases, pH scale
Chemicals: red cabbage juice solution, vinegar, lemon juice, baking soda, soap solution, water
Equipment: 5 test-tubes, plastic pipette
Procedure: The teacher shows an experiment in which substances having different acid-base properties (e.g. water, vinegar, baking soda) are transferred into the test-tubes containing the solution of red cabbage juice. Students should get familiar with a colour chart like the one shown below [6].

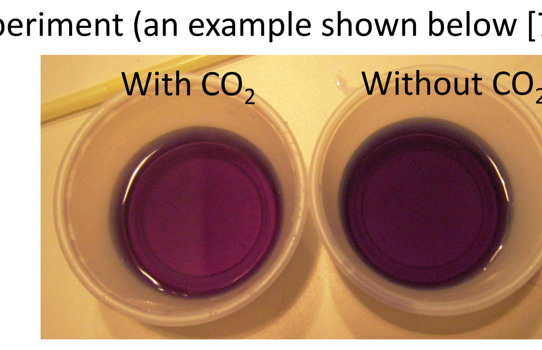
All students discuss with teacher's guidance the following questions:

1. What happens with red cabbage juice colour when acids, bases or neutral substances are mixed with it?
2. What properties are indicated by red cabbage colour changes?

The teacher should ensure that all students understand what is an acid-base/pH indicator and what can be detected by its colour changes.

PROBLEM – detecting carbon dioxide by using red cabbage juice

Introduction: short analysis of the text about respiration and its products
Chemicals: 3-5ml of red cabbage juice, exhaled air
Equipment: 2 test-tubes or cups, drinking straw
Problem: The teacher asks students how can they detect carbon dioxide in the exhaled air with the usage of red cabbage juice
Procedure: Students discuss in their teams how to design an experiment in which diluted red cabbage juice solution will be exposed to the exhaled air. They formulate a hypothesis and prepare the plan of an experiment (an example shown below [7]).



After the experiment, students discuss in their teams following **Critical thinking questions:**

1. What happens when exhaled air is insufflate to the red cabbage juice solution?
2. What are the evidence that exhaled air contains carbon dioxide?
3. Why did the solution become acidic ?
4. What other indicators can be used to perform this experiment?

After short oral reports, all students discuss their results.

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