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Paweł Cieśla, Małgorzata Nodzyńska

The study of basic everyday chemical knowledge of undergraduate students of non-chemical branches of natural sciences

Introduction

Colloquial and scientific knowledge of students, misconceptions and their impact on understanding and learning new content;

Colloquial knowledge is the oldest genre of knowledge. It can be characterized with following features:

- Vagueness and lack of precision;
- Low level of abstraction;
- Poor argumentation of beliefs, low information content.
- It is not a result of a conscious use of research methods, it can be understood as a side-product of practical people's activity.
- The criterion of colloquial knowledge is common sense.

On the other hand, scientific knowledge is based on strong rule of rationality: the degree of conviction with which one propounds some claims should correspond to the degree of its justification. That differentiates scientific knowledge from the colloquial one. Moreover, scientific knowledge is:

- the result of the use of certain scientific methods and seeks to explain the various phenomena;
- theoretical – it examines the characteristics of things and the laws that govern them;
- highly structured, has predictive power, the heuristic power (detection of new facts and relationships between facts).

Psychological aspects of colloquial knowledge: *negative transfer, generalization of the stimulus*

Psychological research on the techniques of learning and memorizing information indicate the influence of previously mastered theories, definitions, skills or behaviors on the acquisition of later parts of material (Buchodolska, Włodarski 1977; Włodarski 1971). This impact can be positive, because thanks to earlier actions one can remember a new material easier – **a positive transfer**. There may also be a negative effect. It takes place when the earlier parts of the material "block" the understanding of new knowledge. It is called a negative transfer. This overlap of previous experiences with new ones may be manifested in a direct way

(so-called *specific transfer*), when the transfer refers to a specific, single activity that is transferred.

In chemistry, a negative specific transfer occurs when information known from autopsy of everyday life gains new chemical meanings (e.g. kitchen salt – spice widely used at home. It has a salty taste, is soluble in water, it forms white crystals. On the other hand, salts are family of chemical compounds, often not salty, not always water soluble, and with different colors, finally their chemical properties often are different than properties of the kitchen salt.).

Negative specific transfer also occurs when introducing concepts in environmental and nature lessons in primary school (Sawicki 1981) when a teacher refers to colloquial, common connotations of that concepts instead of earlier correct defining those concepts basing on scientific knowledge. Finally, the negative specific transfer can occur when a new, more detailed, more difficult and more complicated theory is introduced instead of another simplified one introduced in the previous stages of education. Therefore, it was decided to investigate how the functioning of chemical concepts in everyday life and using them without proper defining in the lessons (e.g. "nature") interferes with the process of their proper functioning in chemical education?

Non-specific transfer – refers to the methods and techniques of learning. The impact of the earlier stage of education is greater when the exercise consists not in the mechanical mastery of the elements of knowledge, but on the understanding of the general principle. Non-specific transfer in chemistry occurs when constructing definitions of new concepts, students build them on the basis of schematics of the terms previously known (e.g. the definition of salts students try to build often based on a known scheme of acid or base definition). In psychological studies, concerning the impact of the originally mastered terms, or imaginations, on the understanding of subsequent parts of the material, there are two more terms: proactive inhibition and transposition.

Proactive inhibition occurs when two different reactions are responsible for the same stimulus. This situation obviously causes a negative transfer, the greater the more varied these reactions are. In chemical education, proactive inhibition often happens, for example, when for one stimulus – term – a definition, chemical and physical properties, methods of obtaining, and common connotations of a given concept are assigned.

Transposition is a reaction not to specific stimuli – notions, but relations, and dependencies between them. In the process of chemical education, we often refer to relationships or relations that appear between the discussed terms. However, it has not been studied so far as this process takes place in the minds of students in chemistry classes.

Generalization of the stimulus – a phenomenon in which the response conditioned by an experimental stimulus also manifests itself in relation to many other stimuli present in the experimental environment (which the experimenter may not even realize, while the animal notices them). Counteracting this phenomenon, if necessary, the experimenter performs conditioning differentiating to the moment when he is sure that the expected reaction occurs only on the proper stimulus. The

lack of differentiation conditioning leads to paradoxical behaviors described as magical dependence.

Kahoot! as an examination tool

After numerous attempts with various forms of online tests to check students' knowledge, the Kahoot was chosen (https://kahoot.com). It is a widespread and free game-based learning platform that makes the learning process fun – it may be useful for learning any subject, in any language, on any device. Its main advantage (which decided about the choice) is the fact that it is not necessary to have a lot of computers within the classroom for testing because students can use their own smartphones, tablets and notebooks to answer. Since every remote controller (i.e. smartphone) is assigned to a given student (by entering the student's name), all information (about the answers and the time of answering) is registered in the system, individually for each examined person. Questions are displayed using the projector on the screen, and the answer symbols are displayed on the students' remote controllers – smartphones, tablets (Fig. 1.).

The system gives immediate feedback. The correctness of the answer is displayed to the student on his cellphone immediately after answering the question. Additionally, on the general board, a ranking is displayed after each question (the sum of the previous correct answers and points for the response time – the faster the student answers the question, the more points he gains). This introduces an element of competition to the exam or test. After the test the teacher can analyze the test results. The data collected during the test are stored in a spreadsheet and pre-designed statistically. Those data can also be processed later using Excel or other spreadsheet. This makes it easier for the teacher to analyze the test result.

Kahoot allows to be set in one of two modes:

- Individual work – each student works on his own,
- Group mode – students can work in groups; then one phone/tablet is used by several students.

Although Kahoot seems to be the most friendly from the market, it also has its drawbacks. The most important advantages and disadvantages of Kahoot are discussed below:

advantages

- Kahoot test database contains more than 13 million ready to use tests (the number of tests is still growing). These tests are mostly in the public domain so the teacher can just use those available tests as they are or prepare own test by changing those ready to use test. Those ready tests can also inspire a teacher while creating his own test from the beginning.
- Ease and speed of test creation.
- Possibility of using upper and lower indexes (priceless for chemists).
- Possibility of setting the response time (from 5 seconds to 120 seconds).
- Possibility of adding a photo or a video (or its fragment – the user can set the time from which the video starts and when it should end while presenting it to

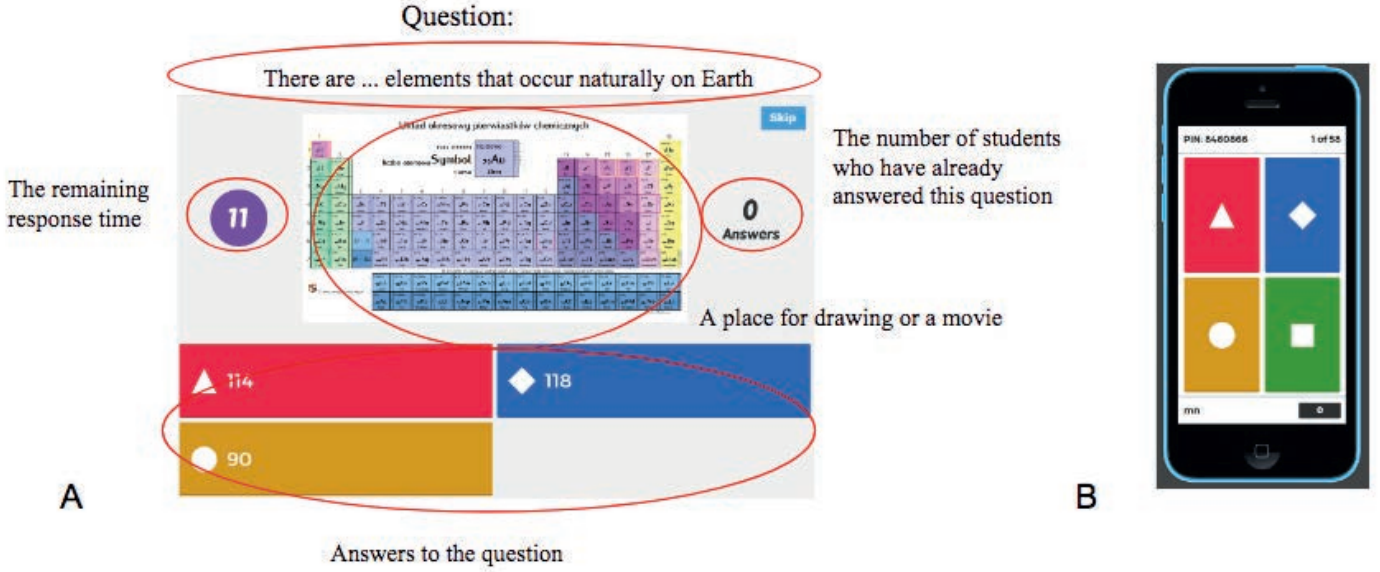

Fig. 1. a) question displayed on the screen; b) answer panel on the student's remote controller.

the students – time of presentation of the film is not included in the response time) from YouTube.
- It is possible to analyze the students' responses (both individual students results as well as their response time for particular questions). The initial analysis is carried out by the program itself.
- Through the usage of traditional tests it is difficult to check the laboratory skills of students - the ability of observing and drawing conclusions based on those observation. The hardcoppied versions of tests usually contain a verbal description of the experience, based on which the student has to make conclusions – the accuracy of such pseudo-laboratory tests is doubtful. It can be assumed that such tasks at first check the ability of understanding written text. In contrast the use of films presenting experiments (including image and sound) in the Kahoot tests creates a task similar to the one in real laboratory – the situation for pupils in which they were able to answer the same questions however really based on observations.
- Possibility of importing questions from spreadsheet.
- The results of the test are available immediately.

disadvantages

– Difficulty of checking the skills for which open type of questions is required, for example, checking the ability of writing equations of chemical reactions, drawing structural formulas.

– Element of competition (after each question a list of 10 top is displayed) – not every student feels well with it, especially during the exam.

– Students need to answer the same questions at the same time. Some prefer to quietly bend over the test and solve tasks in preferred order instead of compulsory one.

– Difficulty in assessing how much time students will need to answer the individual questions

– The need of using electronic devices during the exam.

The research

As stated above it was decided to investigate how the functioning of chemical concepts in everyday life and using them without proper defining in the lessons (e.g. "nature") interferes with the process of their proper functioning in further science education?

The research were carried out using a kahoot test. The questionnaire contained 13 closed questions and required choosing the correct answer from 2 or 4 possible. The questions are presented in table 1.

The research group consisted of 91 students of various non-chemical branches of studies, such as biology, geography, physics, and pedagogy (prospective teachers of early education)

Table 1. Questions presented to students in frame of the test.

Question	Time for answer	Answer 1	Answer 2	Answer 3	Answer 4	Accompanying medium
Q1: Are all acids acidic?	10 sec	YES	NO			The picture of oil (including oleic acid), and apple (contains malic acid)
		Incorrect answer	*Correct answer*			
Q2: The picture shows boiling water. Gas bubbles within a liquid containing bubbles of...	20 sec		oxygen	water vapor	carbon dioxide	The picture of boiling water, inside the liquid gas bubbles
		Incorrect answer	*Incorrect answer*	*Correct answer*	*Incorrect answer*	
Q3: Is salt always salty?	10 sec	YES	NO			
		Incorrect answer	*Correct answer*			
Q4: The drawing and description of the experiment are shown below. Which of the given explanations is correct?	60 sec	Candle consumed oxygen from the air and water took its place	CO_2 formed in the reaction dissolves in H_2O better than O_2.	Drawings and description are incorrect, water cannot rise up.	The heat of a burning candle sucks in water.	The picture of showing the experiment.
		Incorrect answer	*Correct answer*	*Incorrect answer*	*Incorrect answer*	
Q5: Do the following description of the physical characteristics of glucose affects all sugars?	20 sec	YES	NO			A list of physical properties of glucose
		Incorrect answer	*Correct answer*			
Q6: Water vapor can be observed in the picture shown below ...	60 sec.	As gas bubbles in a vessel (erlenmeyer flask)	Over the vessel.	Both answers are correct.	None of the answers is correct.	The picture showing boiling water in an erlenmeyer flask
		Correct answer	*Incorrect answer*	*Incorrect answer*	*Incorrect answer*	

Q7: Is the construction (shape) of a snowflake related to the shape of the water molecule?	10 sec	YES	NO			The photo of a snowflake
		Correct answer	*Incorrect answer*			
Q8: What is burning in the figure below (what is responsible for the visible flame)?	10 sec	melted paraffin	candlewick	Paraffin vapors		The photo of a burning candle
		Incorrect answer	*Incorrect answer*	*Correct answer*		
Q9: Do you know why ice density is lower than water density? (for the substance is the other way round)	5 sec	YES	NO			
		Correct answer	*Incorrect answer*			
Q10: Does the magnet attract all metals?	5 sec	YES	NO			
		Incorrect answer	*Correct answer*			
Q11: There is a glass full of water and ice. What will happen after heating and melting the ice?	60 sec	Water will pour out of the glass.	The glass will be full of water.	The water level in the glass will drop.	It depends on the amount of ice in the glass.	**Photo** presenting the situation described in the question.
		Incorrect answer	*Correct answer*	*Incorrect answer*	*Incorrect answer*	
Q12: What does the movie show?	30 sec	Syringe is leaky, air enters inside	Water boils under reduced pressure	Mixing of air and fluid	Two answers are correct	**A video** showing a boiling water under reduced pressure
		Incorrect answer	*Correct answer*	*Incorrect answer*	*Incorrect answer*	
Q13: Is combustion possible only in the presence of oxygen?	30 sec	YES	NO			**A video** showing underwater burning.
		Incorrect answer	*Correct answer*			

Results of the research

For each correct answer, the student received 1 point. The maximum number of points that students could obtain in the test was 13. The average result of the test is 4.8 of correct answers to 13 questions, which is 36.8% of the possible number of points. The detailed analysis how many of researched persons achieved particular number of points i.e. how many questions they answered correctly is shown in figure 2. One person did not score any point. No-one had more than 9 points.

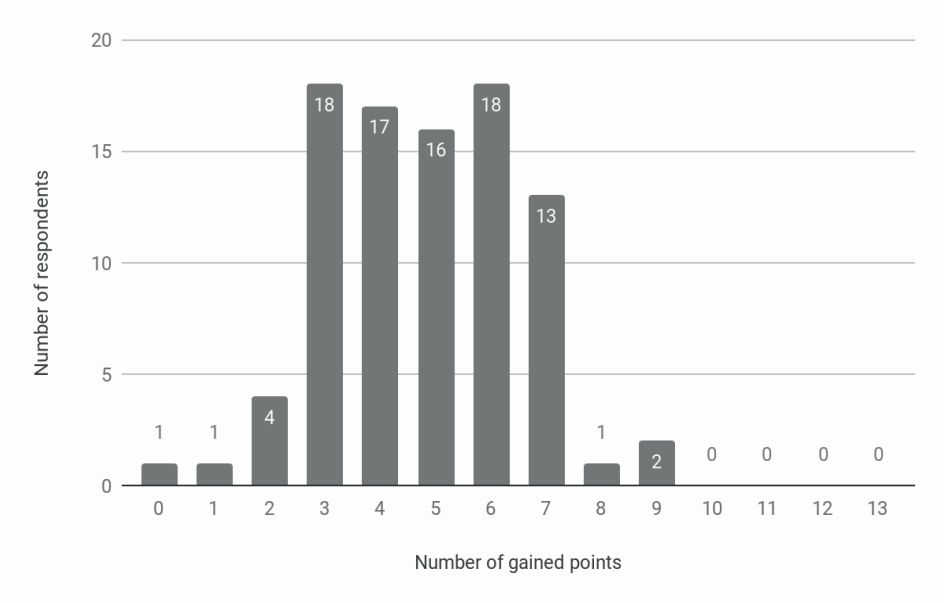

Fig. 2. Number of persons who received particular number of points in the test.

Figure 3 shows the percentage of respondents who answered correctly to specific questions. The results show that only two questions were answered satisfactorily. Less than 38% respondents answered correctly eight of the thirteen questions, including 4 questions they answered at the level less than 13%. A comparison of the answers given to questions Q9 and Q11 shows that the declarative knowledge (Q9) of students sometimes deviates significantly from the actual one (Q11). Questions Q7, Q10 and Q13 required one of two responses, so the results may be overstated due to the higher probability of giving the correct answer in a random way.

Conclusions

Considering that most of the questions related to the situation in everyday life, the obtained results show a very low level of chemical knowledge in the subjects. Respondents usually indicated answers that matched their colloquial knowledge – learned at the early levels of education, when definition of some concepts is incomplete and superficial. The colloquial knowledge is much stronger than scientific one. This knowledge has not been transformed, i.e. a negative transfer took place. Research

has shown that it is important to investigate what is the relationship between the formulation of the definition and its mastery and understanding by the students.

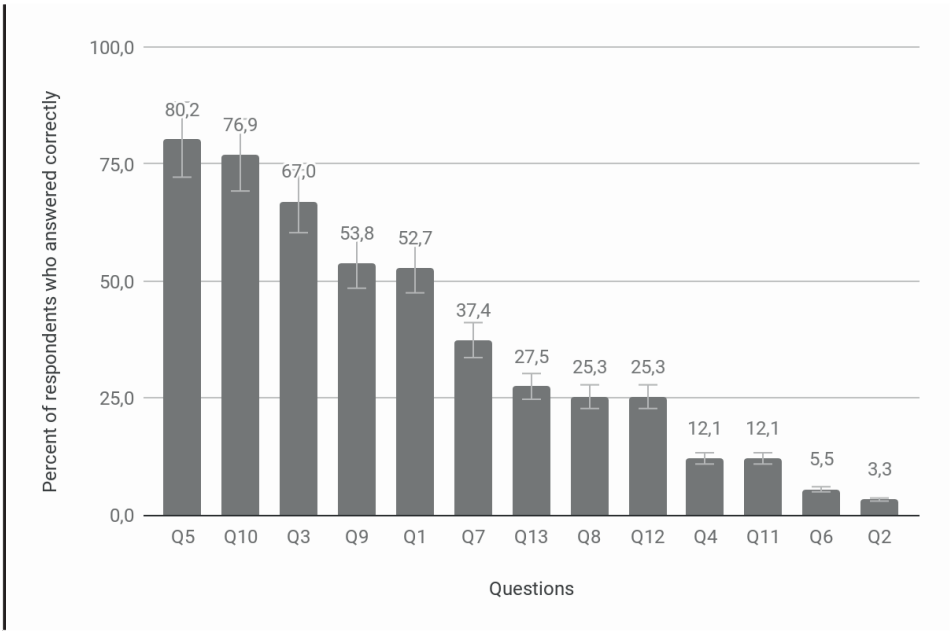

Fig. 3. Percent of respondents who answered particular questions correctly.

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Abstract

As colloquial knowledge may have significant impact on understanding and learning new content it was decided to investigate how the functioning of chemical concepts in everyday life and using them without proper defining in the lessons (e.g. during natural science lessons) interferes with the process of their proper functioning in further science education.

The research was carried out among students of biology, geography, physics, and pedagogy using Kahoot tests. The results revealed that colloquial knowledge is much stronger than scientific one at the examined area and negative transfer took place.

Key words: scientific knowledge, colloquial knowledge, negative transfer

Paweł Cieśla, assistant professor
Department of Didactics of Natural Sciences, Institute of Biology, Pedagogical University of Cracow, Poland
email: pawel.ciesla@up.krakow.pl

Małgorzata Nodzyńska, associate professor
Department of Didactics of Natural Sciences, Institute of Biology, Pedagogical University of Cracow, Poland
email: malgorzata.nodzynska@up.krakow.pl