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ARE FUTURE CHEMISTRY TEACHERS PREPARED TO PERFORM CHEMICAL EXPERIMENTS AT PRIMARY AND SECONDARY SCHOOLS?

CZY PRZYSZLI NAUCZYCIELE CHEMII SĄ PRZYGOTOWANI DO PRZEPROWADZANIA EKSPERYMENTÓW CHEMICZNYCH W SZKOŁACH PODSTAWOWYCH I ŚREDNICH?

Abstract: Our contribution is devoted to study the ability of future chemistry teachers to organise pupils' observation of chemical phenomena. In this article measuring of multi-level means is described, which should denote a readiness of probands to perform an observation during carrying out chemical experiment. It is based on the assumption that well-prepared observers are able to work actively and to propose alternative solutions, because of their deep understanding of a procedure. In next part of this article the results of a research carried out at Faculty of Natural Sciences in Bratislava are analysed. The research was also aimed to detect if students are prepared to perform chemical experiments without a risk that they will be confused by a procedure or different course of experiment as they had expected.

Keywords: chemical experiment, future chemistry teachers' education, observation, procedure of chemical experiment, research in chemistry didactics

Introduction

The students use to feel chemistry as very difficult subject. Why? One of the reasons of this situation could be the fact that during the chemical reactions we are able to observe the changes in macro-world, but the explanation of the core of these changes is found in micro-world, which we cannot observe directly. Further, chemists use the special symbols or relatively complicated 'language' to write down the chemistry phenomena.

For that reason the connections between the description of observed phenomena and their explanations appear very difficult to pupils. They have a lot of problems with the observation itself. It is not an obvious skill as we can see at students' laboratories. To see

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something does not mean to observe it. If we want the pupils will be able to observe the changes carrying out during chemical reactions, they should first learn how and when to notice the changes and learn to link the observations with theoretical knowledge.

The observation skill is useful not only in chemistry laboratory, but it has a wide application in everyday life. For that reason this topic attracts attention of chemistry teachers and didactics all over the world [1-10]. Performed researches are aimed at a description of present situation. The results show that the pupils are able to observe no more that one from each tree changes, which could be observed during chemical reaction. Another problem that we can see in the area of observation is harmonious connection among the parts of observation process that contains observation of changes during reaction, their explanation and their record in chemical 'language'.

Where we see the main cause of these problems? The teachers do not meet the constructivist approach to the formation of the relevant knowledge and skills. We do not give enough time to real observation and follow-up explanation of the observed phenomena. There are also a lot of time needed to cope with the symbolic recording and wider interpretation of observed changes. If the pupils obtained knowledge and skills linked with the observation in gradual process without time pressure they would not have any problems with the connection of the constituent steps of this process.

Our chemistry curriculum is full of new terms, definitions and tasks, so time became the main problem. Because of the time some parts of cognitive process are shortened inappropriately. Usually the real observation is the most cut. We mostly work on an assumption that if we teach students the principles of the processes, so they will know what they would see really during practical experimentation. It is also supposed that the students will understand how they should observe the changes and write down and explain their core. But the reality is different. If we asked students what they observed, for example during the electrolysis of copper(II) chloride, we often obtained the answer like this: "Anions of chlorine go to the anode, loss the electrons and they are oxidised on the chlorine atom. Cations move to the cathode, where they gain the electrons and are changed to the cupper atoms." On these and similar statements it is seen that predominantly the theoretic explanation of the electrolysis was explained. The real observation, the changes that are seen with our senses, was not used to come out from it. The connection between the macro and micro world was not used.

This indicates that the teacher have the significant function in the looking for the reasons of this state, but also in the searching for the ways for its improving. We would like to aim our attention on this aspect of the described subject in our contribution.

Aim

We concentrate on a finding if preparation of future chemistry teachers is adequately efficient from the point of view of organisation and control of pupils' observation.

Methodological issues

We created a special test called 'The Test of Observation Prediction' (TOP) which should indicate readiness of the probands to perform the observation during carrying out chemical experiment. We can characterise TOP as a double-level test. It consists of two parts. The assembling of the TOP was proceeded from the assumption that good prepared observer is able to seek single phenomena actively, anticipate them according to deep understanding of a procedure. He or she can feel the uncertainties, insufficient accuracy of a description of the constituent steps of the procedure. He or she is also able to predict alternative observations depending on real performing of the single parts of the experiment.

The next part of the TOP should indicate knowledge of the probands touching the bases of described experiment.

According to a short outline of the experiment the probands should:

- predict the single observations during carrying out the procedure,
- discover the uncertainties, incomplete information in the procedure,
- write down the alternative changes in the system and observations arising from the uncertainties of the procedure.

The last part of the TOP consisted of a didactic test, which indicated the probands' knowledge from the described issue.

The TOP had this assignment:

First part

You should carry out following experiment:

1) Pour vinegar in the quarter of a test tube.
2) Add a drop of universal indicator and stir the solution.
3) Then add a bit of solid sodium hydrogen carbonate.
4) After all add several drops of hydrochloric acid solution.

The subtests:

1) In points write what you could observe within carrying out of the experiment described above. Try to write all possible changes (observations).
2) Write, in which steps the instructions are not precise enough and if it is possible to observe different changes, results. Explain why you think these steps are not accurate.
3) Write the alternatives of observation because of inaccurate instructions.

Second part - Test

1) Write the reaction of acetic acid with sodium hydrogen carbonate.
2) Write the reaction of hydrochloric acid with sodium hydrogen carbonate.
3) Write the reaction of hydrochloric acid with sodium acetate.
4) How the value of pH changes by adding some amount of sodium hydrogen carbonate in the vinegar.
5) Circle true sentences:
   a) Vinegar is aqua solution of acetic acid.
   b) Acetic acid is a light yellow liquid.
   c) Acetic acid has a typical smell.
   d) Sodium acetate is soluble in water.
   e) Sodium acetate has a typical smell.
   f) Sodium carbonate is soluble in water.
   g) The colour of acid-base indicators depends on pH.
   h) Bicarbonate oxide is gas.
   i) Bicarbonate oxide has a typical smell.

Realization

141 students took part in our research. Participating students were studying for future chemistry teachers at master degree at Faculty of Natural Sciences Comenius University in Bratislava. In the first part of the research, students solved the first part - tasks No. 1-3 and

immediately after they solved the didactic test. They were not allowed to make changes in the first parts of the TOP after starting to solve the questions of didactic test.

Results and discussion

At the beginning of this part we would like to predict possible students' answers according to the expected level of their knowledge.

First part - Task No. 1

- 1st step of the procedure - vinegar is a solution, colour of vinegar, smell of vinegar
- 2nd step of the procedure - indicator is in form of a solution, colour of indicator solution, smell of indicator solution, almost no change in volume of solution in test tube, miscibility of these two solutions, change in colour of solution
- 3rd step of the procedure - colour, state, structure (crystalline or powdered) and smell of sodium hydrogen carbonate, dissolving of hydrogen carbonate in vinegar solution, change in colour of solution, escaping of bubbles, foaming and fizzing, thermal effect of dissolving, enlarging of volume of mixture, not dissolved hydrogen carbonate at the bottom of the test tube
- 4th step of the procedure - hydrochloric acid is a solution, colour of the solution, smell of the solution of hydrochloric acid, miscibility of the solutions, change in colour of the mixture, escaping of bubbles, foaming and fizzing, warming of the mixture, enlarging of volume of mixture, dissolving of the undissolved hydrogen carbonate at the bottom of the test tube

First part - Task No. 2

- 1st step of the procedure - undetermined exact volume of vinegar, undetermined exact concentration of vinegar, undetermined exact volume of test tube
- 2nd step of the procedure - we do not know which universal indicator was used, unspecified concentration of indicator solution, unspecified exact volume of added indicator solution, carefulness of the mixing is not specified
- 3rd step of the procedure - unspecified mass of hydrogen carbonate, undetermined structure of hydrogen carbonate, purity of hydrogen carbonate is not specified
- 4th step of the procedure - concentration of acid is not specified, number and size (volume) of acid's drops is not determined

First part - Task No. 3

- 1st step of the procedure - different intensity of vinegar colour according to used brand of vinegar or coloured by caramel
- 2nd step of the procedure - change in colour does not have to be observed or only for a short time in the moment of adding a drop, no after mixing, there can arise layers with different colour after no good mixing, different colours according to used indicator
- 3rd step of the procedure - all hydrogen carbonate does not have to be dissolved, solution does not have to change the colour after adding only small amount of hydrogen carbonate, we do not have to notice escaping of bubbles and fizzing, mixture can boil over the test tube, we do not have to notice the change in temperature, we do not have to notice the change in volume

- 4th step of the procedure - we do not have to notice the change in colour of solution, we do not have to notice escaping of bubbles and fizzing, mixture can boil over the test tube, we do not have to notice the change in temperature, we do not have to notice the change in volume, undissolved hydrogen carbonate does not have to dissolve

Figure 1 describes the results obtained in the research. We can arise from a qualitative analysis of the results that students were principally able to notice changes in colour related with a presence of a universal acid-base indicator. Second direction linked with the formation of carbon dioxide and other observations connected with it was mentioned less often. Different physical properties were stated even less. These statements are truth in principle for all levels of TOP. There is also obvious that the students only mentioned the solutions directly and clearly linked with the single steps of the procedure. In case that the given solution could be formed only after linking and logical processing of many different information the frequency of its occurrence was markedly lower. (See a possible formation of carbon dioxide after adding of hydrochloric acid.)

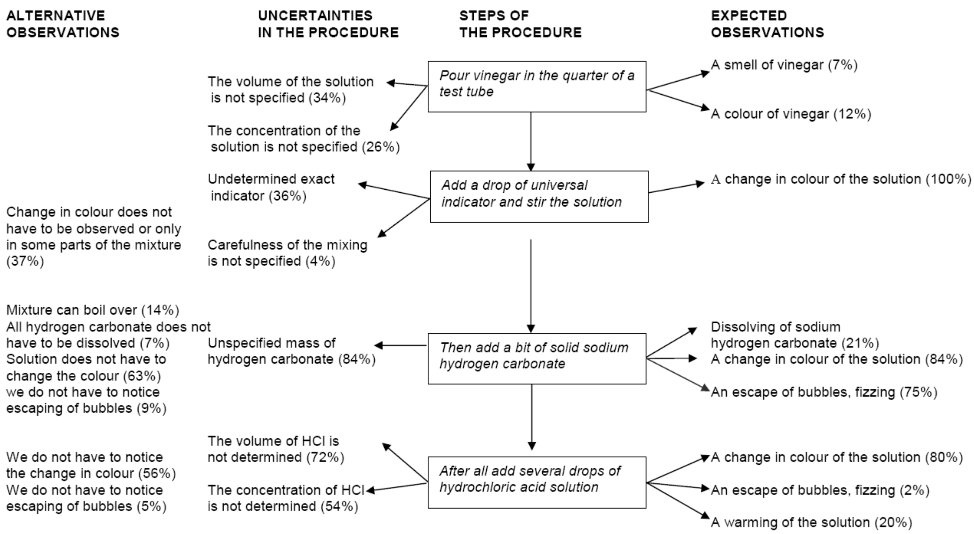

Fig. 1. A qualitative analysis of obtained results

The quantitative aspect of probands' performance is shown in Table 1.

In next part of quantitative analysis we searched success rate. As we can see in Table 2, average number of solutions mentioned by students oscillates from 6.88 to 16.92% in tasks 1-3, while the test was solved on 74.47%. We can conclude from this difference that the students knew an explanation and theoretical interpretation or chemical notations of single processes sufficiently. But the first part of the observation process - observation itself, would be difficult for them. As it follows from this part of analysis the main attention was paid to theoretical chemical notation and explanation of chemical phenomena during chemistry lessons. The preparation on observation is not sufficient in all directions from point of view of our postulates - neither in using information included in procedure to estimating possible observations nor in discovering of uncertainties included in procedure nor in prediction of possible variations in observation considering the inaccuracy of given procedure.

Table 1

The results of probands in TOP

	First part Task No. 1	**First part Task No. 2**	**First part Task No. 3**	**Second part - Test**
Average	3.4	2.2	1.1	9.7
Variance	2.49	1.92	1.19	3.00
Standard deviation	1.58	1.39	1.09	1.73
Maximum	9	6	5	13
Minimum	0	0	0	5
Standard skewness	3.157	3.157	4.312	–2.170
Standard kurtosis	2.898	0.493	0.891	–0.644

Table 2

The success rate of probands in TOP

	Number of possible solutions [points]	**Average number of probands‘ solutions**	**Success rate [%]**
First part - Task No. 1	31	3.4	10.96
First part - Task No. 2	13	2.2	16.92
First part - Task No. 3	16	1.1	6.88
Second part - Test	13	9.7	74.47

The bases of the analysis of mutual associations of single levels of TOP are shown in Table 3.

Table 3

The correlations between the items in TOP

		First part Task No. 1	**First part Task No. 2**	**First part Task No. 3**	**Second part Test**
First part Task No. 1	Sperman correlations		0.3376*	0.4237*	0.3938*
	R-squared (relation’s tightness)		10.6045%	17.3788%	15.6457%
First part Task No. 2	Sperman correlations	0.3376*		0.5652*	0.1631
	R-squared (relation’s tightness)	10.6045%		33.6787%	2.508%
First part Task No. 3	Sperman correlations	0.4237*	0.5652*		0.2780*
	R-squared (relation’s tightness)	17.3788%	33.6787%		7.6127%
Second part Test	Sperman correlations	0.3938*	0.1631	0.2780*	
	R-squared (relation’s tightness)	15.6457%	2.5086%	7.6127%	

* Statistical significance at the 99% confidence level

The values of correlation coefficients between the tasks and tasks on the one side and test on second side (except the relation between task 2 and test) show a statistically significant relationship at the 99% confidence level. The correlation coefficient and R-squared values indicate a lower or moderately strong relationship. The results of task 2 and 3 relate most tightly.

As the Pearson correlation coefficient shows a statistically significant relationship between the results of task 1 and test and also between task 3 and test, we can say that the students' preparedness to observe proceeding phenomena are to a certain extent influenced by their theoretical knowledge. On the other hand we can state that this ability is also determined by other factors as the level of intellectual abilities, skills and habits related with experimental work.

Conclusions

The results of our research indicate that future chemistry teachers are able to understand a core of chemical experiment's procedure only to a certain extent. They have problems with linking of information from a given procedure with real performing of experiment and with meaningful activities during observation, evaluation and interpretation of data obtained during carrying out an experiment. Some parts of observation are unseen to them to a large degree. Most frequently students notice the changes in colour. We can also say that described means showed that the theoretical base of chemical experiment - its explanation, interpretation and notation, is most emphasised part of chemical experiments. This part causes only small problems to students. Little attention is paid to real observation, which should be the first part of chemical experiment.

In our research we also verified an applicability of TOP. We can say that this multi-level test can be used to discover students' abilities to perform chemical experiments meaningfully or to rule pupils' carrying out of experiments without a danger that they will be confused by uncertainties in a procedure or different course of experiment as was awaited.

The findings acquired during performing our research can contribute to improve preparing of future chemistry teachers for carrying out chemical experiments and ruling pupils' cognitive operations during doing experiments.

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CZY PRZYSZLI NAUCZYCIELE CHEMII SĄ PRZYGOTOWANI DO PRZEPROWADZANIA EKSPERYMENTÓW CHEMICZNYCH W SZKOŁACH PODSTAWOWYCH I ŚREDNICH?

Abstrakt: W naszej pracy badaliśmy przygotowanie przyszłych nauczycieli chemii, czy jest ono wystarczająco efektywne z punktu widzenia organizacji i demonstracji uczniom zjawisk chemicznych. W artykule opisano średnie wartości wielopoziomowych pomiarów, które powinny wskazywać gotowość badanych do prowadzenia obserwacji w trakcie trwania eksperymentu. Bazowano na założeniu, że dobrze przygotowany obserwator jest w stanie aktywnie działać mimo niedostatecznej dokładności opisu doświadczenia i jest w stanie zaproponować alternatywne rozwiązania. W kolejnej części artykułu przeanalizowano wyniki badań przeprowadzonych na Wydziale Nauk Przyrodniczych w Bratysławie. Badania miały także na celu ocenę przygotowania studentów do wykonywania eksperymentów chemicznych bez ryzyka, że zostaną oni zaskoczeni innym od oczekiwanego przebiegiem doświadczenia.

Słowa kluczowe: eksperyment chemiczny, kształcenie przyszłych nauczycieli chemii, procedura eksperymentu chemicznego, badania w nauczaniu chemii