Experiments in teaching and learning natural sciences

the monograph edited by: Małgorzata Nodzyńska, Paweł Cieśla, Agnieszka Kania

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EXPERIMENTS IN TEACHING NATURAL SCIENCES

Małgorzata Nodzyńska, Paweł Cieśla

Today, probably no one imagines teaching science without experiment. There is the view, which defined the process of education in the natural sciences as a representation of the research process. Therefore, in developing training methods should aim to improve students' independent thinking. Chemical experiment requires the action and activity of both the students as well as teachers. With it, students learn responsibility for their actions, safety and hygiene of work. It should be recalled that the chemical experiment does not equate to the laboratory test or excercise. Laboratory test is a set of operations which is performed to achieve a certain effect, but the experiment goes a step further - the person performing, it in addition to the same activities, must plan the experiment and also interpret, verify and use the results. Despite that, most chemistry teachers and specialists in chemistry education uses these two terms interchangeably. They are agreed on one thing: laboratory method is the basis for teaching chemistry.[Galska-Krajewska & Pazdro] In the literature we can meet various classifications of chemical experiments. Experiments can be performed by teachers (then this is a show or demonstration) or by the students themselves (then this is an exercise). It is a classification of experiments due to persons who conducts the experiment. However, one of the most used is theclassification by Burewicz and Gulińska:

"1. Illustrative experiment - the teacher tells the students about its purpose, methods of its execution, observations and conclusions as well;

2. Research experiment, that is, one which is directed by the teacher, however, the students themselves record observations and draw conclusions;

3. Problem experiment, where the students are planning the experiment to solve stated problem, carry the experiment out and solve that problem" [Burewicz & Gulińska].

After the analysis of this classification can be considered that the first-mentioned experiment is a kind of a recipe, and only the third can be called a chemical experiment. The main function of ilustrative experiments is instructive - allow students to develop new skills or to practice the skills acquired earlier. Students have direct contact with various chemical reagents and laboratory hardware. Experiments are used to guide students how to read certain phenomena, ie assimilate certain facts by students.

Research in recent years show that teachers are increasingly choosing demonstrations and decide to abandon the self-perform experiments by students. It should be noted, however, that is not always possible to perform the experiments in a chemical laboratory, and worse when there is no available room chemical laboratory (the other rooms are usually not equipped and not adjusted to carry out chemical experiments). Teachers are also focused on ensuring the safety of students, which is not always possible in a big group of pupils. The other difficulty is the fact that teachers do not have enough time to prepare the laboratory equipment and reagents for experiments. Students themselves sometimes express doubts towards working with chemicals, for example, such as acids or bases.[Nodzyńska & Paśko] In addition, the student must be prepared to properly carry out the experiment. First a pupil defines the purpose of the experiment and describes the experiment in an appropriate way (laboratory equipment, reagents, procedure and scheeme or figure). Then he carries it out with and writes observations. In the last step the student does the analysis of the results and make conclusions.

The student should exhibit activity, willingness to act, independent and creative thinking. Chemical experiments are ment to help students acquire their knowledge. Therefore, it is important to find a way for students to recognize the experiment not as a necessity and not as just another part of the course, but as an interesting way of learning.

In this aspect, the modern trends in science education are consistent - students should have the

research attitude and independently seek to acquire knowledge. For example, one can not imagine teaching chemistry without performing experiments. The teacher should be for the student as a guide who shows him the way he should go, so that through the laboratory work the student could develop his knowledge and skills. Students are then resourceful, self-reliant and creative. They learn not only logical, quick thinking, but also train their manual skills. Even while performing simple chemical experiments, students have an opportunity to recognize, define the physical and chemical properties, use, and receive materials that surround them in everyday life.

By linking what students are doing in the chemistry lesson with what they see in their own homes, with their friends, in their environment, it is possible to efficiently and quickly memorize the information and gaining the skills.

It is important that the teacher at the beginning properly introduced the topic and then presented the prodedure of working for the student. Students, who work with the instruction, practice reading with understanding comprehension, which skill is required at the secondary school tests, and in a later stage of education.

In addition, good instruction directs students to important concepts and makes the focus on the most important elements. However, during the execution of the experiment, teacher participation should be limited to a minimum - to a supervising role. The conclusions and observations are given either during or after the experiment. The best solution is to formulate conclusions in the discussion among students in the classroom [Burewicz & Gulińska].

Once again it should be emphasized that the experiment is of great importance to the student, because in addition to the impact on the development of skills, is also a source of emotional knowledge - motivation to learn and to shape his interest. The more interesting lesson, the students will be more willing to participate in it. A student is seeking to do something that in his eyes is important, and treat various activities as improving his competences. The motivation for the students' work is the properly chosen teaching method. But keep in mind that every student has different needs and each student acquires knowledge in a different way. The teacher should know the students - their educational and emotional needs as well as their interests and capabilities. In this way it will be easier choosing the appropriate method of transfer of knowledge to them. Nevertheless, it can be assumed that the chemical experiments that the student performs independently, are motivation - firstly to actively participate in the lesson and secondly to learn of the topic. It will be easier to remember that glucose has reducing properties when they see either metallic silver precipitated on the walls of the tube (Tollens test) or the brick color in the Trommer test, than when we say that glucose has reducing properties, as in an alkaline environment it is present in the chain forms, that it has free aldehyde group. The lesson, which includes elements of laboratory method is thus interesting and triggers positive emotions in students.

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Małgorzata Nodzyńska, Paweł Cieśla

Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

EARTH – A SOMEWHAT BIGGER LABORATORY FOR SCHOOL PHYSICS

Krzysztof Służewski, Grzegorz Karwasz

Rationale

Indications for teaching Science in XXIth century abstract from specific disciplines, like Physics or Geography and come back to treating so-called natural sciences as a unique entity. Newton's mechanics and Maxwell's laws disappear from school curricula and become substituted by "Light and energy" [Jordan, 2009] or "Energy sources and use" [Millar, 2011].

In Poland, the recent reform of school programmes, so-called "Programme basis" removed teaching Biology, Chemistry, Geography and Physics from upper secondary school, substituting them by a general Science (MEN, 2008). Science will be taught to all students that choose Humanities as their specialization. The present detailed programme of Science seems a puzzle crosswords: in vertical the four specific subjects and in horizontal 25 themes, starting from science methodology but including "Laughing and crying", "Biggest and smallest" and so on. The new programmes were decided in 2007 but no textbooks were prepared in advance and no university proposed any specific training for teachers. In 2012, in view of prompt entering the new CVs to schools, the Ministry allowed any teacher of the four specific subjects to hold the whole course of Science. For all these reasons, searching for interdisciplinary paths in-between, say, Physics and Chemistry [Gagoś & Karwasz, 2012], Physics and Geography [Karwasz & Chojnacka, 2012] but also Geography and History [Karwasz, 2014] becomes urgent.

Didactics of Physics Division at Nicolaus Copernicus University Toruń is recognized as a pioneering center for interactive didactics. Simple objects, commonly called "toys" are used by us to substitute traditional (and frequently annoying) school experiments. This way of extra-scholar teaching Physics, first introduced in Poland some 15 years ago [Karwasz, 1998] obtained a really unexpected diffusion and step-by-step growth up to national science centers.

Earth is one of the larger laboratories, that one can imagine, and only the Universe is larger. Phenomena of Geophysics include optics (rainbow, hallo, blue sky, mirages etc.), thermodynamics (weather patterns, ocean currents, volcanoes etc.), mechanics (Earth's orbit, Earth's interaction with Moon, a flattened globe, mountain formations), radioactivity (age determining, radioactive energy balance) and others.

In present work we outline some experiments which can be used in interdisciplinary teaching Geography: how some of complex phenomena like climate patterns can be illustrated by simple physical laws. Experiments presented can be repeated by teachers, seen in science centers or even done by pupils at home. Experiments described here will receive an internet virtual mirror at Didactics of Physics Division .

Laws of Physics

Phenomena on a great, Earth-like scale obey the same physical laws as the laboratory experiments. Just few physical laws determine the main behavior of atmosphere, lithosphere, hydrosphere. Moreover, due to the approximately closed nature of the system Earth+Sun +Moon, these phenomena are governed by quasi-static equations. The equation can be, additionally, simplified by separating the vertical and horizontal coordinates [Peixoto & Oort, 1984]. To the first approximation, the mathematics behind Earth's phenomena is not complex We will use these theoretical indications while illustrating Geophysics by our simple experiments.

I. Shape of Earth

The shape of Earth is usually referred to as "geoide" what is a tautology: Earth's shape is "earth - like". To the first approximation the shape of Earth is an ellipsoid – a sphere flattened by the quick rotation of the globe, like a bulk of clay flattens on the potter's rotating plate, see our experiment with a rotating spring in fig. 01.



Fig. 01. Rotating spring flattens with increasing velocity of rotation - the same as planets.

A more exact determination of the ellipsoid is not trivial. The question was posed already by Copernicus on first pages of his "De revolutionibus". He asked why water does not flow down from a spherical Earth. Copernicus used Aristotle's way of reasoning – "because water is heavy so it fills up hollows in the soil". Now, after Newton, we know that a correct answer is because of centrally acting gravitational force. But the question on the shape still remains.



Fig. 02. The gravity force FG, acting towards the center of Earth sums up with the centrifugal force F0 acting horizontally on this picture, giving the effective gravity force Q. The effective gravity is stronger on the poles than on the equator. If Earth were a sphere (fig.02a), the effective gravity vector would show a component along the surface of Earth. This would cause the water flowing towards equator. The shape of Earth is ellipsoid (fig. 02b) in a way that the effective gravity is in every point perpendicular to Earth's surface. The latter phrase is the definition of the geoide.

To illustrate a flatted Earth's ball, a picture like in fig. 02a is usually shown. But it is wrong! If Earth were like that on fig. 1a, the effective gravity (i.e. the centrally acting gravity force and horizontally in fig. 02a acting centrifugal force) would have a component along the Earth's surface. This would mean that waves of kilometric heights would wash up the surface of Earth in a continuous way: the effective gravity force can not have a surface-along component! The effective gravity force must be perpendicular to the surface of Earth, or rather opposite: the surface of Earth is such that the gravity force is perpendicular to it in every point. A flattened sphere, i.e. an ellipsoid, as in fig. 02b. satisfies this condition.

Defining Earth's shape by the point-to-point vertical vector of gravity is somewhat clumsy. Geographers use another definition: they show the height over the sea level, like in fig. 03a. The lines shown in fig. 03a, called in Polish "poziomica", i.e. "level-lines" are the lines of a constant height. In Physics we call them lines of a constant potential energy, i.e. "equi-potential" lines. They apply to electrostatics [see for ex. Sadowska & Karwasz, 2011], to gravity [see for. ex. Karwasz & Chojnacka, 2012] and to other physical fields as well. Now, we have an exact definition: geoide is a shape defined by an equipotential surface of the gravity. In other words, it is the shape of Earth if totally covered by water, like in the question postulated by Copernicus. "Also marine waters are arranged to form a spherical shape [...] as land and water lay on a gravity center of the Earth, which is also the centre of its volume".



Fig. 03. The sea level is the reference level to determine the height on Earth's surface (fig. 03a). Rivers flow along the maximum difference of the level, what correspond to the maximum vicinity of the equipotential lines (fig. 03a). The vector of force is always perpendicular to the surface of water, like in the rotating aquarium (fig. 03b). Both pictures illustrate that the effective gravity force acts perpendicular to the effective gravity equi-potential lines.

We are not able to show centrally acting gravity force vector, perpendicular to Earth's surface like in fig. 02b, but we can illustrate this concept by a rotating flat aquarium, see fig. 03b. Both the surface of Earth and the surface of water rotating in aquarium are perpendicular to the force vector. In the case of aquarium the gravity is vertical and the centrifugal force, rising with the distance from the rotation axis, is horizontal. As a result the surface of water is a paraboloid, see fig. 03b. On Earth the surface of water would by an ellipsoid, if no other effects were present. In every case, the gravity measured with a plumb-line is always perpendicular to the sea line, see fig. 04a.

Effective gravity depends on many factors, like the distribution of mass inside Earth, oceans and continents continents, land and see tides, and presence of mineral reservoirs. A dedicated satellite GOCE sent by European Space Agency in 2010, flying on a low (150 km) orbit has measured the equipotential surface over the Earth with a centimeter precision. Measurements done confirm earlier results that the geoid surface differs from the ellipsoid by up to 100 meters in some regions. The geoid is higher than ellipsoid in the region of Indonesia and Iceland but lower than the ellipsoid in the region of Himalaya, see a map on fig. 04b. We are not able to explain it without the mathematical expression for the gravitational potential V.



Fig. 04a. The geoid surface is defined by sea level; it is always perpendicular to the gravity force, as measured by plumb-line (beach of Sopot on the photo).

Fig. 04b. The difference between the geoide and ellipsoid surface – dark gray are negative differences, mid-tone gray are positive differences. The geoid is about 100 m below ellipsoid in the region of Indian Ocean (and less in Himalaya) and 100 m above the ellipsoid over Iceland and Indonesia. The Indian Ocean basis is formed of light, calcite rocks, Iceland is the region of the outflow of heavy, magmatic rocks from Earth's depths.

The gravitation potential created by a mass M at a distance r in expressed by a simple relation $V = G \frac{M}{r}$, where G is the gravitational constant. In the case of geoide, if the mass beneath is smaller

r, where G is the gravitational constant. In the case of geolde, if the mass beneath is smaller (rocks are light), in order to keep a constant potential, the surface of the geoide must be below the ellipsoid surface. In fact, both Himalaya and the seabed of the Indian Ocean are made of a thick layer of light (limestone) rocks, so the geoide surface there is below the ellipsoid; opposite in Iceland, with relative heavy basalts flowing continuously out from the volcanic ridge in the middle of Atlantic Ocean – the geoide is above the ellipsoid, see fig. 04b.

II Age of Earth, Universe and Moon

The age of Earth is sure more than the biblic 6000 years, but even prominent scientists like Lord Kelvin hundred years ago calculated it as about 100 million years. There is an easy way to estimated the age of Earth using one of the subjects listed in "Science for XXI century" [Millar, 2011], i.e. the radioactivity. The subject is important as a part of social consciousness in energetic questions, cancer treatments, health security and so on. Usually, the radioactivity is associated with uranium or plutonium, but these are not the only cases: the radioactivity was discovered in uranium and plutonium is one of the first chemical elements created artificially, but radioactivity is present everywhere, so can be shown easily (and with a high didactical profit) in school laboratories.

The experiment we propose is the radioactive decay of potassium, ⁴⁰K. A portable radiation counter used for security monitoring in scientific laboratories is simple and relatively cheap, see fig. 05a. A small amount of any substance containing potassium (we use KCl) gives a measureable signal on the counter – several counts per second. Potassium ⁴⁰K decays into stable ⁴⁰Ar in β-reactions ⁴⁰K \rightarrow ⁴⁰Ar + e⁻ + <u>v</u>, i.e. emitting an electron and antineutrino. The well known half-life time of ⁴⁰K is 1.2 billion years, but we can check it experimentally.

In order to estimate the age of the sample containing potassium we need to know only the percentage of the radioactive ⁴⁰K isotope (which is 1.2·10⁻⁴). The amount N' of potassium ⁴⁰K nuclei decaying in a second is proportional to the number of these nuclei N₀ in the sample and the decay rate λ , according to equation N'= λ N₀. The decay rate is related to half-life time T_{1/2} through the relation T_{1/2} = ln 2/ λ .

In the proposed experiment, some 1.5 g of KCl (i.e. about 0.02 mol, the amount chosen to make calculations simple) is placed in a thin layer (to avoid the absorption of the emitted electrons in the sample), just below the counter. Measuring about 8 counts/sec (with the background level of 10

about 1 count/sec) but knowing that half of the electrons is emitted down and detector's efficiency is about 50%, we estimate the number of decays as some N'=28/sec. With Avogadro's number of $6 \cdot 10^{23}$ atoms/mole one gets totally 12×10^{21} potassium nuclei, out of them N₀=14 \cdot 10^{17} being ⁴⁰K. These numbers give λ =N'/N₀ $\approx 28/14 \cdot 10^{17}/s \approx 2 \cdot 10^{-17}/s$ and finally T_{1/2}= $3.5 \cdot 10^{16}$ s, i.e. $1.1 \cdot 10^{9}$ yrs, in good agreement with the precise value.



Fig. 05. The age of Earth. **a**. Radioactive decay of potassium ⁴⁰K isotope; even if the contents of the ⁴⁰K isotope is relatively small, a simple radioactivity tester shows about 8 decays/second from a thin layer of potassium salt below its head. **b**. Scientific determining Earth's age from radioactive decays; measurements in zirconia crystals for ¹⁴⁷Sm and ¹⁴⁴Nd ratio indicate the age of Earth as 4.567 billion yrs [Boyet & Carlson, 2005]. **c** Big crystals in granite sample from Helsinki indicate slow cooling; the age of this sample is about 3.5 billion years (collection GK).

The age of the potassium sample must be, therefore, at least several billion years: the initial amount of 40 K decays very slowly, but thanks to a great numbers of atoms in a small sample, the signal is measureable. The same idea stays behind the determination of the age of Earth. Different nuclei decay with various times - the most abundant out of uranium isotopes ²³⁸U decays with $T_{1/2}$ =4.4 billion yrs but radon ²²²Rn with $T_{1/2}$ =3.8 d. The ²³⁸U radioactive decay starts a series, as following: ²³⁸U $\alpha \rightarrow$ ²³⁴Th $\beta \rightarrow$ ²³⁴Pa $\beta \rightarrow$ ²³⁴U $\alpha \rightarrow$ ²³⁰Th $\alpha \rightarrow$ ²²⁶Ra $\alpha \rightarrow$ ²²²Rn $\alpha \rightarrow$ ²¹⁸Po $\alpha \rightarrow$ ²¹⁴Pb $\beta \rightarrow {}^{214}\text{Bi} \beta \rightarrow {}^{214}\text{Po} \alpha \rightarrow {}^{210}\text{Pb} \beta \rightarrow {}^{210}\text{Bi} \beta \rightarrow {}^{210}\text{Po} \alpha \rightarrow {}^{206}\text{Pb}$ (stable), with specific lifetimes for every nuclei. The contents of slowly decaying isotopes forms a fingerprint for the age of the rock. Modern radiation detectors allow to trace very rare isotopes. Choosing rocks and mineral geologically almost stable, like micro-crystal of zirconia, it is possible to determine their age. One of such recent determinations gave the age of Earth (and therefore of the whole Solar System) as 4.567 billion years [Boyet et al., 2005]. Hectic searches are under way to find the oldest possible rocks solidified on Earth, see for ex. [O'Neil, 2008]: there are several possible candidates, like Acasta gneisses. We note, that all those solidified rocks coming from Hadean Eon are now found in drifted-out continental plates, like Greenland, South Africa, Australia. A sample of granite with extremely big crystals, testifying slow cooling (i.e. hot Earth) comes from Helsinki airport area and is some 3.7 billion years old, see fig. 5c. Many pieces of old granites were dragged from Scandinavia to Poland by glaciers and each pupil can make an own collection.

Tracing specific (especially heavier than Fe) chemical elements gives the information on the supernova explosion than formed the Solar System: due to the physical reasons [the nuclei binding energy, see for ex. Karwasz & Więcek, 2012] elements heavier than Fe must be formed inside neutron-like stars. To go earlier in time, towards the Big Bang, one finds another fingerprint, left just some 300,000 after the beginning of the Universe. It is so-called cosmic background radiation: it comes from the moment that "darkness separated from the light", see a mosaic from St. Marco's Cathedral in Venice from XII century in fig. 06a. Physically, the initial Universe was so dense, that any emitted light was immediately absorbed by other atoms. We observe such auto-absorption in yellow (sodium) road lamps [Karwasz et al. 1999]. When the Universe became less dense, the trapped light was freed. Due to the expansion of the whole Space, the light that belonged to the visible range now has a longer wavelength and is observed as microwaves – by

ground-based radiotelescopes like that in Piwnice near Toruń, see fig. 06b or by space missions like Planck. The latter gave the most accurate number for the age of the Universe -13.82 billion years. But the background cosmic radiation can be seen on the old TV – some 1/3 of the "noise" on the screen comes from the beginning of the Universe, fig. 06c.



Fig. 06. Determining the age of Universe. **a**. Biblical separation of light from darkness in the Book of Genesis, according to the imagination of the artist of the XIIth century is shown on the mosaic at Venice cathedral. **b**. the microwave cosmic background radiation can be measured ground-based radiotelescopes (at UMK observatory in Piwnice), a more precise map was obtained by Planck space mission. **c**. The primordial microwave signal can be seen also on an old TV screen.

Moon is an inseparable companion of Earth. Apollo missions brought pieces of rocks, resembling much those present in Earth's external part, i.e. in the mantle. This indicates that these rocks once were part of Earth. Some 100 million years after formation, the Earth was hit by an object of the size of Mars. The encounter tore a powerful piece of matter and debris, which, it is believed, in 24 hours formed the Moon. It was the most violent day in the history of Earth. At the beginning of its history, the Moon orbit the Earth closer than today. Now, each year, moving away from her by about 4 cm per year. Moon is the main reasons for ocean tides, and these are tides which favored the life's climbing from waters to the land.

By a strange coincidence angular sizes Moon as seen from Earth are almost the same as the angular size of the Sun seen from Earth, compare with a photo from Apollo mission in fig. 07a. The period of rotation of Moon around its own axis is the same as its orbiting time around Earth; in other words only half of Moon is visible from Earth. Such a celestial mechanics correlation not unique in Solar System; for example a 2:3 resonance governs the movement of Mercury. However, to slow down a period of rotation some non-conservative forces must be present in the system. For the Moon+Earth system these are oceanic tides which can absorb the energy and lead to the adjusting of the rotation and circulation periods.



Fig. 07. **a**. As seen from the Moon it is difficult to say whether Moon accompanies Earth or Earth follows the Moon (photo NASA Apollo 11); **b**. the system Earth - Moon can be compared to canoes from Polynesia: the natives are sailing on a larger boat, but the smaller one is needed for balance. **c**. A funny bicycle rider remains in balance thanks to a small ball on the other side of the lever.

The crucial role of Moon for Earth are not only tides. Numerical simulations showed that without Moon the Earth's axis Moon would enter big oscillations just in 10 million years time. In other words, a much smaller and 81 times lighter Moon, posed at relatively small distance (about 10 Earth's circumferences) exercises a stabilizing function on our planet. This is like Polinesia navigation on a boat stabilized by a smaller one, see fig. 07b. Numerous objects, like that on fig. 07c illustrate the same concept.

III Earth' internal structure

Earth's internal structure can be studied with a great detail (i.e. down to the depth of the ironnickel core and with a few kilometer resolution) detecting seismic waves. The two physical types of waves – longitudinal and perpendicular propagate with different velocities, get attenuated and reflected in different manners. A slinky spring [Karwasz et al. 2005] kept with a adjustable tension can be used to show these properties of both types of waves.

Earth's interior is called core, see fig. 08a, but its dimensions are unusual for what we typically name as a core – the radius of Earth's core is half of the planet radius. The core is composed of iron and nickel, remnants of the end of nuclear reactions in pre-Sun [see more on nuclear reactions in Karwasz & Więcek, 2012]. The velocity of longitudinal wave indicate that it probably contains also some lighter elements, maybe silicon. But nobody reproduced in lab the iron-nickel-silicon alloy under such great pressures, so do not know a proper crystallographic structure. Cognitivistically, we compare Earth's structure to an avocado fruit – a big hard core, a soft mantle and a thin, harder skin ("crust"), see fig. 08b.



Fig. 08. The internal structure of Earth. **a**. A double naming of the layers in Earth – a Greek one (lithosphere, mesosphere) and Mohorovičić-like (crust, mantle). **b**. Illustrative section of avaocado-like Earth. **c**. Lava lamp, with two liquids of different thermal dilatation, similar to different mineralogical phases (olivine, magnesium silicates and so on) shows a mechanism of the vertical convective transport in the Earth's mantle.

A soft, semi-liquid mantle is unique among the planets of the Solar System. A right balance between the heat coming from the interior (some 20 TW) and created from radioactive decays (next 20 TW) of uranium, thorium and potassium contained in a form of light compounds (oxides, silicates) in the mantle assures this energy flow. Thanks to it the surface plates are still, after 4.5 billion years, in constant motion. The negative outcome are earthquakes but the silicate-carbonate rock transitions in liquid magma assured a supply of CO₂ to atmosphere, and therefore the pleasant, 33 K greenhouse effect [see for ex. Karwasz & Służewski, 2013].

We show a vertical convective motion inside the mantle using a so-called lava lamp, see fig. 08b. Two liquids with different thermal expansion coefficients, heated from below, mix up-anddown, like lava rising in volcano channels. In fig. 09a we show an aquarium heated from below, where the liquefied wax floating on water surface once cooled forms plates-like pattern, with some hills, mountains and trenches. Continental plates will move for next hundreds of million years, as follows from recent computer modeling, in 50 mln yrs America and Eurasia will collide at the North Pole. Oceanic plates are thinner, but heavier, and continental one are light, like the ice plates covered by snow on the Baltic sea, see photo 09c.



Fig. 09. **a**. Paraffin wax on the surface of the water shows the distribution of the tectonic plates (photo A. Karbowski). **b**. America and Eurasia will collide in some 50mln years at the North Pole [source: Physic World, March 2013]. **c**. Continental and oceanic plates resemble pieces of sea-water ice: some of them thicker, covered with snow, some of the barely floating on the sea surface, like on this photo taken from Sopot molo (M. Karwasz).

IVAtmosphere and oceans

A dominant feature in understanding atmosphere mechanics and thermodynamics is the diversified in vertical layers and geographical latitudes, infrared-radiation budget, see for ex. [Karwasz & Służewski, 2013]. The warm, wet (and therefore light) air rises above the equator, dries-up at the edge of the troposphere (giving tropical rains) and is convected, like in lava lamp, towards tropics. There, dry, cold (and heavy) sinks down to the ground at Sahara, Gobi and Kalahari regions. This is so called Hadley cell, coupled with a weaker cell above our latitudes. But for the horizontal transport, this is so-called Coriolis force that governs the weather, see fig 10a.



Fig. 10. Coriolis force is due to rotation of Earth: objects moving from equator towards the poles find the Earth's surface too slow. **a**. The mathematical formulation with vector products is rather difficult but the rule is simple: on the Northern hemisphere the air moving North is deviated to the right. **b**. Coriolis force makes the air flowing out from the region of high pressure (like above Azores on Jan 6th 2014) circulate in clockwise direction. **c**. The air flowing-in towards the pole of low pressure circulates (on Northern hemisphere) anti-clockwise.

Coriolis force is related to the fact, that Earth rotates; physically in a rotating reference frame apparent (i.e. not predicted by the II Newton's law) are present. We already mentioned the centrifugal force. Coriolis force appears if an object tries to move in a rotating frame – it is like a mysterious force "cutting legs" when we walk on a rotating plate. Its mathematical formulation is not so easy, see fig. 10a. Coriolis force is the cause that winds flowing out-of center (i.e. at high-pressure poles, see fig. 10b) tend to rotate clockwise on the Northern hemisphere (and anti-clockwise on the South hemisphere). Low-pressure poles behave to the contrary – rotate anti-clockwise on Notherrn Hemisphere, see the weather forecast in fig. 10c.

Coupled with the Hadley cell, Coriolis force is also the reason for so-called trade winds, used by Columbus when he travelled west in October and came back East in March, see fig. 11a. The route of Columbus is a nice example of closing loops in atmosphere and hydrosphere circulation: oceanic currents flow in one direction on the surface and close the loop in depths. This is also the case of Gulf Stream – waters heated in Sargassic Sea flow towards Europe, cool down in the region of Iceland and come back in depth, like we illustrate it in the experiment in fig. 11b.



Fig. 11. **a**. Columbus used the seasonal variation of trade winds to complete his travel (Source: Wikipedia). **b**. Similar closed in depth loops characterize oceanic currents; we show it in experiment with hot coloured water rising up in aquarium and cooled by the ice on the right corner.

Didactical hints

As an attentive reader surely noted, the presented topics follow always a similar line:

1) formulation of the cognitive problem concept ("what is the shape of Earth?"), 2) simplified illustration (flattening ball made of spring ribbon), 3) a more rigorous explanation (ellipsoid), 4) modern, scientific follow-up (GOCE experiment). This is clearly a constructivistic-like path [see Karwasz, 2013], needed for the modern, interdisciplinary school, not only in Poland.

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Krzysztof Służewski, Grzegorz Karwasz Didactics of Physics Division, Faculty of Physics, Astronomy and Applied Physics, Nicolaus Copernicus University, Toruń, PL <u>ks@fizyka.umk.pl</u>, karwasz@fizyka.umk.pl

FACTORS INFLUENCING THE PARTICIPATION OF HIGH SCHOOL STUDENTS IN A PHYSICS LABORATORY

Louis Trudel, Abdeljalil Metioui

The context and purpose of the research

In high school, the science laboratory has always been considered an essential part of science education in secondary schools since it allows students to engage in scientific inquiry. Students can think by themselves, explore new ideas, and draw their own conclusions. Moreover, the student acquires manual and intellectual skills that will help him solve the problems of modern life. While emphasizing the distinctiveness of the laboratory in teaching science, Hofstein and Lunetta (2004) note that research has not yet identified educational situations in which the laboratory would be the most effective in terms of learning. In this regard, participation is passive and at a low cognitive level [Kind, Kind, Hofstein & Wilson, 2011]. In general, the objectives and methods used in the laboratory are chosen by the teacher. The student participation concerns mainly the procedures they follow to the letter according to teacher's instructions and directions provided in laboratory notebooks. It is therefore not surprising that the planning skills and the way to conduct experiments are lacking among students [Hoffstein & Lunetta, 2004].

Following these findings, our research attempts to answer the following question: How can we enhance students' participation in the laboratory so that they are active and engaged in a true scientific investigation? To answer this question, one must first come up with a definition of students' participation in terms of behaviors that are expected in the science laboratory and that may be observed in a quantitative and objective way. In our research, participation is defined as the time spent by the student to achieve tasks in the science laboratory.

With this definition in mind, research has identified several factors that may influence student participation in the laboratory, either associated with teaching/teacher, or with students' characteristics. With respect to teaching, one may say that laboratory activities are executed primarily in small groups. However, this type of grouping could be detrimental to participation because, most of the time, students are not supervised by an adult [Furtak, Seidel, Iverson & Briggs, 2012]. Moreover, behavior rules in the laboratory are less rigid and the prevailing rate, determined by students, is slower. Considering the lack of guidance in the laboratory, students' preparation to laboratory may be important to foster students' participation in it [Davidowitz, Rollnick, & Fakudze, 2005]. Hence, a discussion that takes into account the students' conceptions about the phenomena studied and that helps them to construct new knowledge from it is likely to change the way they engage in laboratory activities, that is to say their participation [Kind, Kind, Hofstein & Wilson, 2011].

With respect to factors related to students' characteristics, the discovery of a possible link between students' participation in the laboratory and academic success oriented our research to identify factors that may influence their participation [Furtak & al., 2012]. With regard to gender, boys generally participate differently than girls in the laboratory [Alexopoulou & Driver, 1997]. When boys and girls work as a team in the laboratory, the task of girls is usually restricted to observe and record data while boys tend to manipulate the instruments and perform the experience [She, 1999]. Considering the factors above, our research objective is to evaluate the influence of these factors (prior discussion, type of task in the laboratory, gender, and academic achievement), and their reciprocal interactions, on students' participation in laboratory.

Methods

The research was conducted in a French Canadian high school. The sample of high school students was drawn from a population following an introductory course in physics. The sample contained one hundred and two students (122), sixty girls (60) and forty-two boys (42). These students were divided into four groups. Two teachers volunteered to experiment the teaching strategy with their two groups each. The first teacher had many years of experience in teaching while the second one was new to the profession.

To measure participation, we used the observation grid of participation of Tobin (1986). According to this grid, students' participation in the laboratory is comprised of the following categories: 1) attention, 2) recall of facts, 3) data collection, 4) understanding, 5) quantification, 6) planning, 7) generalization, 8) non-cognitive, 9) off-task. A meeting between the researcher and the two teachers a few days before the experiment allowed the less experienced teacher to practice questioning strategies used in the prior discussion, the other teacher observing the practice. Students' participation in one laboratory (preceded by a pre-laboratory discussion) was compared to the students' participation in the other laboratories (preceded by traditional preparation). The science concept of the pre-laboratory discussion was chosen as the equilibrium of forces (as was the following laboratory) while the other science concepts covered in the traditional preparation for the laboratory (and hence the laboratory that followed) were varied: motion in one dimension and two dimensions, relationship between weight and mass, relationship between length and applied force on a spring, free fall motion. A measure of the participation of each student in the laboratory was made randomly each five seconds by two observers with an average degree of agreement of 0,77. Therefore, the effect of students' preparation to laboratory as well as the effect of other factors (gender and academic achievement) on participation was assessed using a multivariate analysis of variance of repeated measures [Howell, 2008].

Results

Inspecting results from Tab. 01, one can see that pre-laboratory preparation had a significant influence on the time spent by the student in the various categories of participation in the first and fourth groups. This difference could also be assigned to a different type of task carried out in the laboratory. Moreover, this difference, in the first group, may be derived from the fact that students of the first teacher were doing the analysis and discussion of their results in the classroom. However, difference, in the fourth group of students of the second teacher, between laboratories' participation were also statistically significant, while his students were conducting the analysis and discussion of their results in the laboratory room.

In all groups, participation significantly influences time spent by the student. Thus, one of the categories of participation is significantly different from other categories. This means that students do not spend the same time in each category. This finding may seem obvious. It encourages us to seek causes of this allocation of time students between the different categories of participation in a laboratory. These differences may be due to how students perceive the task and allocate their time accordingly.

In all groups, there is a significant interaction between laboratory preparation, or the type of laboratory task, and students' participation. Thus, the laboratory preparation, or type of laboratory tasks, will change the time allocation of students between participation categories. This result enables us hope to change the participation of the student in the laboratory using an appropriate preparation or choosing a different type of task in the laboratory.

In the third group, there was a significant interaction between gender and participation. So, in the third group, participation differs by student's gender. In the fourth group, there was a significant interaction between gender, laboratory preparation (or laboratory tasks) and participation. It is reasonable to assume that the influence of laboratory preparation (or the type of task in the laboratory) on students' participation in the laboratory differs according to gender. It is 18

therefore important to consider the gender of the student in the choice of laboratory preparation or the type of task to be performed in the laboratory if one wishes to influence students' participation in the laboratory.

Source of variation	Group ³								
	1	2	3	4					
Lab prep ¹	0,000*	0,794		0,024*					
Achievement X Lab prep	0,635	0,885		0,093					
Gender X Lab prep	0,584	0,807		0,024*					
Gender X Achievement ² X Lab prep	0,480	0,886		0,093					
Participation	0,000*	0,000*	0,000*	0,000*					
Achievement X Participation	0,945	0,439	0,099	0,816					
Gender X Participation	0,193	0,892	0,02*	0,357					
Gender X Achievement X Participation	0,810	0,444	0,310	0,846					
Lab prep X Participation	0,000*	0,000*	0,001*	0,002*					
Achievement X Lab prep X Participation	0,768	0,733	0,382	0,105					
Gender X Lab prep X Participation	0,034*	0,210	0,085	0,076					
Gender X Achievement X Lab prep X	0,711	0,751	0,548	0,628					
Participation									

Tab. 01. Multivariate analysis of factors that may influence participation in the four groups.

Legend:

1: Lab prep stands for preparation to the laboratory

2: Achievement stands for academic achievement

3: Results shown are the probabilities associated with different groups for each variable or interaction of variables (source of variation)

*: To the right of a number, it means that the result is significant at alpha = 0.05

Academic performance does not influence significantly participation nor does it influence indirectly students' participation, by interaction with other factors. This rather surprising result could be explained by the fact that laboratories contain mainly manual activities likely to appeal to students with various academic achievement results. It could also be argued that the laboratories are focused primarily on data collection and stimulate participation of all students equivalently. Indeed, if the laboratories had contained tasks related to planning or generalization, it is possible that the participation of students with high academic achievement would be different from the participation of students with low academic performance.

Conclusions and implications

Our results show that students' participation varies from one laboratory to another. This variation can be explained by the preparation to the laboratory (traditional versus discussion), the different type of tasks asked from students in the laboratory, or a combination of the two. Girls participate differently from boys in the laboratory. Academic achievement has no effect on the participation of students in the laboratory. The identification of the different factors and their relationships should allow us to better understand how students participate in laboratory and develop interventions to improve it.

Regarding the limitations of our research, since the order of treatments assigned to different groups was not made randomly, we cannot eliminate the interaction between treatment and subjects' maturation as a possible source of the effects measured. Furthermore, the choice of a convenience sample does not allow generalizing results to the population of high school students following an introductory physics course. Finally, the approach taken in this research has allowed us to identify some of the main factors likely to influence participation in laboratory. Subsequent studies are needed to determine conditions that encourage students to engage in a genuine scientific approach and thus acquire the scientific skills aimed by high school science curriculum.

1

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Louis Trudel¹, Abdeljalil Metioui²

¹ - Université d'Ottawa

² - Université du Québec à Montréal

Canada

ltrudel@uottawa.ca, metioui.abdeljalil@ugam.ca

IMPACT OF AN APPROACH FOR PROSPECTIVE SCIENCE TEACHER TRAINING IN FRANCOPHONE MINORITY COMMUNITIES UPON THE DEVELOPMENT OF LESSON PLANNING SKILLS

Louis Trudel, Abdeljalil Métioui

Context, framework and purpose

In the last survey conducted by the International Programme for Monitoring Student Assessment (PISA 2012) undertaken by countries member of the Organisation for Economic Cooperation and Development (OECD), Canadian students in minority education systems have achieved results in mathematics and science significantly lower than their counterparts in majority education systems. As a consequence, some of these low achievement students would likely not continue their studies beyond compulsory schooling and might therefore find it difficult to use mathematics and understand scientific events in their daily lives (OECD, 2013). However, science education must provide all young people, from diverse socio-economic and cultural backgrounds, equal opportunities to succeed in their science and mathematics courses and as a consequence being able to integrate society in the highly competitive world of tomorrow. In order to do so, we must help these young people acquire necessary scientific skills through innovative student-centered teaching methods, such as strategies of scientific inquiry [Instance, Lancrin Vincent Van Damme, Schleicher & Weatherby, 2012].

This new way of teaching science demands that the teachers take new roles and change their conception about the nature of science and the acquisition of scientific knowledge [Crawford, 2000]: engage pupils in authentic scientific activities, guide them in data collection and analysis, encourage collaboration between teacher and pupils, favour contacts with the ambient community, model behaviours of the scientists and lead pupils to appropriate the scientific projects in which they are involved. And yet, prospective teachers and those who start in the teaching profession who want to use scientific inquiry strategies face up several obstacles. Indeed, this new perspective often enters in conflict with the way they were taught and their conception of science teaching and learning. Besides, they were not exposed to the scientific inquiry in their own scientific training and as a result do not understand the complexity of this strategy nor its requirements [Windschitl & Thompson, 2006].

This situation creates a paradox which too often unsettles science teachers training programs where it is expected that prospective teachers will accept straightaway precepts and epistemology linked to scientific inquiry without offering them step which takes into account their initial conception and favours their evolution towards a perspective more in line with the program requirements of science courses. So, we should find in prospective science teachers training programs activities encouraging them to get involved in a step of inquiry in relation to their own training, where they have to identify, explore and resolve educational problems which they have themselves identified [Marble, 2006]. These considerations lead us to propose a training approach of science teachers based on the following principles: 1) modifications in the different aspects of knowledge and beliefs of the prospective teachers have to be made in a convergent way; 2) the use of an authentic task of education, such as the planning of lessons, allows to include the different aspects aimed by the prospective physics teachers training [Strangis, Pringle & Knopf, 2006]; 3) integration must be made in a progressive way, a modification in one aspect, even minor, might cause modifications in other aspects, so that training consists of a progressive and iterative refinement of the prototype constructed from and initial representations and knowledge of the prospective teacher [Dorsey & al, 1997]; 4) since the teachers favour the building of pedagogic concepts from lessons plans implementing pedagogic and scientific concepts, a model of a typical scientific inquiry lesson will be given to them to produce on one hand a first planning and on

the other hand to change it according to scientific and pedagogic criteria [Marble, 2006]. As a consequence, the objective of this research is to study the effect of such a training approach on the planning of a strategy of scientific inquiry by prospective teachers.

Methods

The faculty of education of the University of Ottawa is responsible to train prospective teachers so that they could teach in one of the official languages, French or English, in the province of Ontario (Canada). To be admitted to the program, the candidate must detain a first cycle university degree in sciences or in a related discipline. The sample of the students is composed of a class of didactics of the physics of 31 students (10 women and 21 men) who registered in the French part of the program. Following this course, the students are allocated to schools where they make an internship of six weeks.

Data collection and analysis techniques: The progress of prospective teachers in the mastery of scientific inquiry strategies was assessed by using a rubric constituted by three elements: a) group of dimensions to be assessed; b) a scale at calibrated levels; c) statements associated to each level according to the assessed dimension [Nitko, 2004]. To determine the effectiveness of our training strategy, we analysed prospective teachers' planning of scientific activities which they had to hand in at the end of course with the aid of the rubric of scientific inquiry developed by Llewellyn (2002). The degree of mastery of pedagogical scientific techniques of the inquiry is assessed according to the following dimensions: 1) curriculum; 2) presentation of the lesson; 3) engagement of pupils; 4) questioning of teacher; 5) evaluation. According to each of these scales, the levels of performance of the prospective teacher are: 1) traditional approach; 2) explore strategies of inquiry; 3) in transition towards the mastery of inquiry; 4) mastery and practice of inquiry.

Analysis and interpretation of results

Since the lesson plans were accomplished in groups of one to four persons, evaluation which follows relates to each of the groups. Each of these groups had to choose a topic in the Ontario high school physics curriculum of 11th or 12th grade and aimed at one or at several expectations and competences. Besides, these plans had to include a sequence of scientific activities to complete at least one learning cycle [Llewellyn, 2002]. Topics approached by the different groups are the following: refraction of light; mechanical energy; waves; Newton's laws; motion in two dimensions; quantity of motion; magnetic induction; mechanical work; friction; optics. The evaluation of the level of the planning of each group of prospective teachers in relation to the degree of mastery of the strategy of scientific inquiry consists in allocating a note to the group for different criteria linked to every dimension as described above. This evaluation was accomplished by both authors and results from a consensus between them after debate. To allocate a level to a dimension, the majority of the criteria of this dimension had to be at this level. The inspection of Tab. 01 shows that the prospective teachers at the end of course are mostly between level 2 (explore strategies of scientific inquiry) and level 3 (in transition toward the mastery of inquiry). Two groups of students remain rather traditional (level 1) in their planning of scientific activities. One group attained the highest level (level 4) of mastery in inquiry strategies.

Criteria	Groups of prospective teachers									
	1	2	3	4	5	6	7	8	9	10
Curriculum	4	2	3	2	1	3	1	1	1	3
Presentation skills	4	3	3	3	2	3	2	1	1	3
Students' engagement	4	2	3	3	2	3	2	1	1	3
Prospective teachers' questioning skills	4	2	2	2	2	2	2	1	2	3
Prospective teachers' evaluation competencies	3	3	3	3	2	3	2	1	1	3

Tab. 01. Level of mastery of inquiry strategies among different groups of prospective teachers in their planning of scientific activities.

Conclusions and implications

The majority of the groups of prospective teachers having followed the training approach exposed in this research incorporated in their lesson planning dispositions aiming at engaging their future pupils in scientific inquiry. The exploratory character of this research does not allow us to deduct from it that it is the introduction of this training approach that is responsible for this result. Nevertheless, our results support those got by Schwarz and Gwekwerere (2007) which followed a similar approach. The success met in the modification of activities conceived by prospective teachers appears promising although improvements still remain to be made. These are caused by some limits of this approach, especially the necessity to assure the authenticity of tasks, authenticity which is difficult to meet in university context where the training and practice are lived in different places and time. As a result, an improvement to be brought in the training approach would consist in favouring the use of strategies of scientific inquiry worked out by the prospective teachers in the school, for example during their practicum. The feedbacks of the pupils for which these activities are intended would increase their authenticity while giving prospective teachers information allowing them to improve their pedagogic competences in the school context where they will be called to exercise [Marble, 2006].

Nevertheless, some limits in the use of the evaluation rubric are worth being underlined. As such, the definition of levels 2 and 3 seems vague so that it is more difficult to classify the planning of the prospective teachers in these levels. In this respect, it would be appropriate to characterise better these two levels, for example by linking them to distinct approaches in science education [Kariotoglou, Psillos and Tselfes, 2003]. Finally, it is regarding the constraints of time and of resources encountered in teachers' training program that our approach is particularly interesting. Indeed, the choice by the prospective teacher of a physics topic whom will concern his planning, besides the motivation it generates and that is essential to begin and follow in an autonomous way a step of planning, allows to cover more physics contents and to study the characteristics of a variety of methods, resources and of approaches of education than a traditional approach of presentation of pedagogical concepts.

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Louis Trudel¹, Abdeljalil Metioui²

¹ - Université d'Ottawa

² - Université du Québec à Montréal

Canada

ltrudel@uottawa.ca, metioui.abdeljalil@uqam.ca

ACTIVITIES WITH SENSORS IN LABORATORY OF BIOLOGY: STUDENTS' MOTIVATION AND UNDERSTANDING THE ACTIVITIES

Marek Skoršepa, Eva Stratilová Urválková, Petr Šmejkal, Montserrat Tortosa Moreno, Hildegard Urban-Woldron

Introduction

We present the partial study arising from a European project COMBLAB (acronym derived from COmpetency Microcomputer-Based LABoratory) titled *The acquisition of science competencies using ICT real time experiments*, where the researchers from six following universities belonging to five European countries are involved: (i) Universitat Autònoma de Barcelona (Spain), (ii) Charles University in Prague (Czech Republic), (iii) University for Teacher Education Lower Austria, Vienna (Austria), (iv) Universitat de Barcelona (Spain), (v) University of Helsinky (Finland) and (vi) Matej Bel University in Banská Bystrica (Slovakia). The main aim of the project is to design and implement the research based learning materials for students and teaching materials for teachers on the background of Microcomputer-Based Laboratories (MBL). The subjects of the project interest are Physics, Chemistry and Biology.

Methods

Three evaluating tools were administered to students during the performing of each activity: (i and ii) two tests for motivational orientations [Pintrich et al., 1991; McAuley et al., 1989] and (iii) a questionnaire to gain a feedback in order to evaluate the activity and to uncover how students understand it.

The data and results presented in this paper were obtained during the implementation of Biology activities and involve only the Slovak part of the research. The study follows our recent work in the field – an implementation of analogous activities for Chemistry [Skoršepa et al., 2013].

The research in Slovak republic included 117 students (82 female; mean age = 16.9 years, SD = 0.7) from four grammar schools: (1) Gymnázium Andreja Sládkoviča, Banská Bystrica (n = 45), (2) Gymnázium Mikuláša Galandu, Turčianske Teplice (n = 25), (3) Gymnázium Spišská Nová Ves (n = 24) and (4) Gymnázium Jána Chalupku, Brezno (n = 23). None of the participating students had previous experience with MBL in their schools. However, some of them took part in testing of Chemistry activities recently [Skoršepa et al., 2013]. Most of the students performed more than one activity (usually three), therefore totally 266 evaluations were acquired. The conditions in the participating schools didn't allow testing the activities in the local schools. Due to the serious lack of necessary equipment in the schools, all students were invited to perform the activities in the university labs (Matej Bel University).

Motivational orientation of students toward working in MBL

A part of our research was to investigate the students' self-declared perception of their motivational orientations before and after performing the activity. In this study, the issues of students' motivational orientations were studied, particularly the dependence on factors such as gender, a particular activity and a specific school. The students were also clustered into the groups according to their motivational orientations.

In order to distinguish between motivational orientations before and after performing the activity, two research devices - motivational tests, were used:

Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich and his colleagues [Pintrich et al, 1991] for assessing student's motivational orientations and their use of

different learning strategies, which was administered to students before performing the activity (Pre-test).

Intrinsic Motivation Inventory (IMI) originally designed for assessing the subjective experience related to intrinsic motivation and self-regulation [McAuley et al., 1989] administered after realizing the activity (Post-test).

Both of the original research tools are multi-scaled. However, from each of the tools we selected four scales suitable for our purposes (Table 1) where each scale was represented by four items (declarative clauses). Answers to the items were classified on the seven-level Likert scale ranging from "I totally disagree" (1) to "I totally agree" (7).

Do students understand the activities?

In order to validate the activities and to have feedback from students on how they perceive themselves, a questionnaire including 20 items investigating several aspects related to the proposed MBL activities was designed (e.g. understanding the activity and its objectives, activity attractiveness, its difficulty, the development of students' knowledge and attitudes of students toward MBL approach). The questionnaire was administered after performing the activity. Herein, the partial data resulting from the six following items of the questionnaire are presented: (1) I understood the objectives of the activity;

- (2) List the objectives of the activity;
- (3) I needed my Teacher's help to understand the activity;
- (4) It was easy to collect data by means of MBL approach;
- (5) MBL approach helped me to interpret the results (e.g. graphs) correctly;
- (6) I think the activity could be done without MBL.

In Items 1, 3, 4, 5 and 6 as declarative clauses the answers were classified on the four-level scale: 1 - strongly agree, 2 - agree, 3 - disagree and 4 - strongly disagree. In the open Item 2, where students were asked to list the objectives of the activity, the answers were subsequently quantified as follows: 1 - correct answer; 2 - more or less correct answer; 3 - not sufficient answer and 4 - totally erroneous answer.

Results

The presented results arose from the testing and evaluation of four newly designed biology activities: (A) The life of Yeast (Yeast & Fermentation); (B) Wake up, wake up, it's time to get up? (Seed Germination); (C) What makes your heart beat? (ECG) and (D) Nursie, the pressure! (Blood Pressure).

Motivational orientations of students

Tab. 01 shows Cronbach's alpha values for all studied scales. In order to get robust variables only scales with $\alpha > 0.7$ should be considered. It is obvious that the internal consistency of answers within the individual scales is acceptable only in six of eight cases. For two scales of Pre-test (3 and 4) the internal consistency is questionable.

Tab. 01. Scales and reliability coefficien	nts (Cronbach's alg	oha) for motivational orientation of	of students.
Scale (Pre-test)	a	Scale (Post-test)	α
1 Intrinsic Goal Orientation	.77	1 Interest/Enjoyment	.84
2 Extrinsic Goal Orientation	.80	2 Perceived Competence	.78
3 Self-Efficacy for Learning and Performance	.69	3 Effort/Importance	.82
4 Control of Learning Beliefs	.66	4 Value/Usefulness	.78

Correlation analysis show strong relationship mainly within the Post-test scales (Tab. 02) corresponding to the fact that they all relate to intrinsic motivation and self-regulation.

	Scale	Pre1	Pre2	Pre3	Pre4	Post	Post	Post	Post
						1	2	3	4
Pre1	Intrinsic Goal Orientation	1							
Pre2	Extrinsic Goal Orientation	.066	1						
Pre3	Self-Efficacy for Learning and Performance	.595 **	.253 **	1					
Pre4	Control of Learning Beliefs	.412 **	.210 **	.428 **	1				
Post 1	Interest/Enjoyment	.402 **	.184 **	.310 **	.327	1			
Post 2	Perceived Competence	.289 **	.302 **	.504 **	.347 **	.628 **	1		
Post 3	Effort/Importance	.245 **	.426 **	.347	.282 **	.646 **	.679 **	1	
Post 4	Value/Usefulness	.480 **	.205 **	.436 **	.345 **	.787 **	.613 **	.645 **	1

Tab. 02. Correlation matrix (Pearson) for motivational orientation.

**. Correlation is significant at the 0.01 level (2-tailed).

When considering different factors (gender, activity, school) as possible effectors of motivational orientations of students, the following results were found.

Motivational orientations only weakly depend on gender as the statistically significant difference was revealed only in Extrinsic goal orientation (F(1,264) = 10.63, p = .001). More specifically, female students ($M_{female} = 4.61$, SD = 1.21) are more extrinsically motivated than their male schoolmates ($M_{male} = 4.02$, SD = 1.60).

A specific activity was the second factor observed as an effector of students' motivational orientations. However, similarly to our previous study focused on activities for Chemistry [Skoršepa et al., 2013], analysis of variance (ANOVA) revealed no significant difference in variances related to the particular biology activities neither in Pre-test nor Post-test scales. The

6.5 MOTIVATIONAL SCORE 6.0 5,5 ·· Yeasts & Fermentation 5,0 Seed Germination ▲··· ECG 4,5 ···· ··· Blood Pressure 4,0 Scale 1 Scale 2 Scale 3 Scale 4 Intrinsic Goal Extrinsic Goal Self Efficacy for Control of Orienation Orientation Learning and Learning Beliefs Performance

mean values of motivational score belonging to the specific activities before and after performing the particular activity are depicted in Fig. 01 and Fig. 02.

Fig. 01. Motivational orientations before performing the particular activity (mean values).



Fig. 02. Motivational orientations after performing the particular activity (mean values).

In Fig. 01 it can be seen that the motivational scores of students before experimentation are almost the same for all activities in the first three scales. We presume that it is not surprising to obtain the data with no significant differences in Pre-test because before experimentation students don't know the content of activities (their specifics and backgrounds) in detail. As apparent from Fig. 02, the differences in mean values in Post-test scales are more notable but their variances are still not significantly different (ANOVA). However it is important to note that in general students reported relatively high level of motivation in each of the Post-test scales for all activities as in most cases their mean motivational scores are not lower than five.

A particular school seems to be the most influencing factor of motivational orientation of students. The findings from ANOVA revealed a main effect of the particular school on students' perceptions of Intrinsic Goal Orientation (F(3,262) = 12.60, p = .000), Self-Efficacy for Learning (F(3,262) = 6.70, p = .000) and Control of Learning Beliefs (F(3,262) = 6.95, p = .000). The mean values of Pre-test motivational scores related to the particular schools are depicted in Fig. 03. According to the results the students of School 4 reported higher motivational orientations for Intrinsic Goal Orientation, Self-Efficacy for Learning and Control of Learning Beliefs than students from the other three schools.



Fig. 03. Pre-test motivational orientations of students related to the particular school (mean values).

When analysed the Post-test data, the statistically significant difference was found only in one of four cases: Interest/Enjoyment (F(3,262) = 2.79, p < .05). Fig. 04 shows the mean values of Post-test motivational scores when affected by the particular school.



Fig. 04.Post-test motivational orientations of students related to the particular school (mean values).

A hierarchical cluster analysis of Pre-test and Post-test motivational scores (using Ward's method of clustering) revealed that participants can be grouped into three reasonable clusters in both Pre- and Post-cases. A subsequent non-hierarchical cluster analysis (K-means) on the Pre-test data provided the final cluster centers that can be seen in Fig. 05. Interestingly, 79% of participants (38% of Cluster 1 plus 41% of Cluster 3) reporting high motivational scores in Intrinsic Goal Orientation, Self-Efficacy and Control of Learning Beliefs can be divided into two subgroups according to their different Extrinsic Goal Orientations: (i) highly extrinsically motivated (Cluster 3) and (ii) weakly extrinsically motivated (Cluster 1). The last group (Cluster 2) comprises students with plain specific preferences for all Pre-test scales.



Fig. 05. Cluster analysis of Pre-test data (final cluster centers).

Fig. 06 shows that the cluster layering of the Post-test data is more distinct and the three groups of students can be clearly distinguished. The most participants reported high (Cluster 3) or medium (Cluster 1) preferences for all of the Post-test scales. Only 3% of them (Cluster 2) reported almost none specific preference for all scales.



Fig. 06. Cluster analysis of Post-test data (final cluster centers).

Understanding the activities and students' perception of their MBL performing

The complete set of data related to this sub-topic can be seen in Tab. 03. After each of the performed activities most of the students declared that they understood the activity objectives (A: 95.7%, B: 98.6%, D: 100.0%, D: 100.0%). The students usually answered that they strongly agree (1) or agree (2) with the declarative clause in the Item 1. However, after listing the objectives (Item 2), the differences between the particular activities appeared and not all of them were satisfying. In activities C and D more than 80% of respondents listed the correct or more or less correct answers. On the other hand, the objectives of the other two activities (A and B) are probably not so clear for students as only about half of them reported correct or more or less correct answers. Furthermore, in these activities there is an anxious number of students reporting totally erroneous answers (A: 31.8% and B: 44.8%).

,	Tab. 03. St	udents' a	answers to the	e selected	items of the	questionnaire	administered after	performing the
activ	ities (M - 1	nean val	ue; S - score;	T-total:	V% - valid	percent; C% -	cumulative percent	t).
[A (Yeast & Ferm	entation)	B (Seed Germination	C (ECG)	D (Bloo	(Pressure)

Item \ Activity		А(на		mematio)	B (Seed Germination)			e (1eco)				D (Diood Fredshite)				
		N = 47				N = 73				N = 73				N = 73			
-		М	S	V%	С%	М	S	V%	С%	М	S	V%	С%	М	S	V%	С%
1.	I understood the objectives	1.32	1	74.5	74.5	1.30	1	71.2	71.2	1.25	1	75.3	75.3	1.26	1	74.0	74.0
	of the activity	±.62	2	21.3	95.7	± .50	2	27.4	98.6	± .43	2	24.7	100.0	±.44	2	26.0	100.0
			3	2.1	97.9		3				3				3	100.0	
			4	2.1	100.0		4	1.4	100.0		4				4		
			Т	100.0			Т	100.0			Т	100.0			Т		
2.	List the objectives	2.19	1	45.5	45.5	2.63	1	16.4	16.4	1.96	1	37.0	37.0	1.26	1	80.6	80.6
	of the activity	+1 41	2	6.8	52.3	+1.36	2	25.4	41.8	+1.00	2	45.2	82.2	+ 89	2	7.5	88.1
			3	15.0	68.2		3	13.4	55.2		3	27	84.0		3	6.0	94.0
			4	21.9	100.0		4	13.4	100.0		4	15.1	100.0		4	6.0	100.0
			-+ 	31.0	100.0		-+ 	100.0	100.0		4 T	10.1	100.0			100.0	100.0
			T	100.0			T	100.0			T	100.0			T	100.0	
1		I				1				I				I			I
3.	I needed my Teacher's help to understand the activity	2.74	1	10.6	10.6	2.89	1	4.1	4.1	3.11	1	4.1	4.1	3.01	1	5.5	5.5
		±.91	2	25.5	36.2	±.84	2	28.8	32.9	± .77	2	12.3	16.4	± .80	2	15.1	20.5
			3	42.6	78.7		3	41.1	74.0		3	52.1	68.5		3	52.1	72.6
			4	21.3	100.0		4	26.0	100.0		4	31.5	100.0		4	27.4	100.0
			Т	100.0			Т	100.0			Т	100.0			Т	100.0	
4.	It was easy to collect data by	1.38	1	63.8	63.8	1.30	1	71.2	71.2	1.33	1	69.9	69.9	1.32	1	68.5	68.5
	means of MBL approach	±.53	2	34.0	97.9	±.49	2	27.4	98.6	±.52	2	27.4	97.3	±.46	2	31.5	100.0
			3	2.1	100.0		3	1.4	100.0		3	2.7	100.0		3		
			4	100.0			4	100.0			4				4		
			Т				Т				Т	100.0			Т	100.0	
5.	MBL approach helped me	1.21	1	78.7	78.7	1.37	1	63.0	63.0	1.51	1	50.7	50.7	1.49	1	56.2	56.2
	to interpret the results	±.41	2	21.3	100.0	±.48	2	37.0	100.0	± .53	2	47.9	98.6	±.60	2	38.4	94.5
	(e.g. graphs) correctly		3				3				3	1.4	100.0		3	5.5	100.0
			4				4				4				4		
			т	100.0			т	100.0			Т	100.0			Т	100.0	
6.	I think the activity could be	2.55	1	10.6	10.6	3.00	1	5.5	5.5	2.64	1	15.1	15.1	1.26	1	24.7	24.7
	done without MBL	± .87	2	38.3	48.9	±.79	2	15.1	20.5	±.96	2	24.7	39.7	± .44	2	37.0	61.6
			3	36.2	85.1		3	53.4	74.0		3	41.1	80.8		3	27.4	89.0
			4	14.9	100.0		4	26.0	100.0		4	19.2	100.0		4	11.0	100.0
			т	100.0			т	100.0			т	100.0			т	100.0	
1				. 50.0		1	•	- 50.0			-	. 50.0		1	•	. 50.0	

At least 16.4% of the students reported a need of their tutor's help (Item 3). However, the level of such help is different for particular activities. From this point of view, it seems that activities A and B needed to be led by a tutor more frequently than the other two activities (notice a probable relation to the results of Item 2). On the other hand, about 60 to 80% of students didn't need their teacher's help.

Students clearly claimed that it was easy to collect data by means of MBL (Item 4) and MBL helped them in interpreting the results (Item 5). In the first three activities more than half of participants think that they couldn't be done without MBL (A: 51.1%; B: 79.4% and C: 60.3%). Reversely, in the last activity students probably know from their home or a hospital experience that for blood pressure measuring an MBL approach is not necessary.

Conclusion

In conclusion, recognizing the level of students' motivational orientation is needed not only to know the student's interest in performing the MBL activities but also to find out whether the students are competent in filling in the questionnaires used to evaluate the activity tasks (chapter 2.2). We presumed that adequately motivated students are more engaged to the entire process and put more effort to complete the experimental tasks but also to complete the questionnaires. Their answers can be then considered more relevant and valuable for subsequent revision of the activities.

We found out that mainly initial motivational orientations strongly depend on particular school attended by a student and only weakly depend on gender. Moreover, similarly to study devoted to activities for Chemistry [Skoršepa et al., 2013] we didn't reveal a significant effect of particular activity on the motivational orientations. This is in contradiction with our previous study [Urban-Woldron at al., 2013] where Chemistry and Physics activities were processed together. However, we suppose that such dependence is more related to variance disparities between the subjects than inside them. According to our separate findings from Chemistry and Biology, we believe that when a single subject is taken into account, no significant evidence of relationship between the particular activity and motivational orientation appears.

The most of the students reported that they understood the activities. However, after deeper investigation diverse level of understanding was confirmed. Knowing that the revision of activities needs to make them comprehensible for the majority of students, it is our task to pay attention mainly to the activities calling for improvement (activity A and B).

The data from our research is still in progress and needs further processing. It will also be important to compare the Slovak data to the results of the other countries participating in the project. However, the partial results suggest the acquisition of MBL approach to the education with experimental background.

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Marek Skoršepa¹, Eva Stratilová Urválková², Petr Šmejkal², Montserrat Tortosa Moreno³, Hildegard Urban-Woldron⁴

¹ - Matej Bel University, Banská Bystrica (Slovakia),

² - Charles University, Prague (Czech Republic),

³ - Universitat Autònoma de Barcelona (Spain),

⁴ - University for Teacher Education Lower Austria, Vienna (Austria)

Marek.Skorsepa@umb.sk

MBL ACTIVITIES USING IBSE: LEARNING BIOLOGY IN CONTEXT

Stratilová Urválková Eva, Šmejkal Petr, Skoršepa Marek, Teplý Pavel, Tortosa Moreno Montserrat

Introduction

Project COMBLAB

The contribution presents a methodology of creation and implementation of six biology activities based on inquiry education approach and using probeware in laboratory, microcomputerbased laboratory, MBL. Activities were created within a European Comenius multilateral project COMBLAB (competency microcomputer-based laboratory) named The acquisition of science competencies using ICT real time experiments, that is now in its final third year of existence. One of the project objectives is to create synergies among six partners interested in probeware and MBL: (1) Universitat Autònoma de Barcelona (Spain), (2) Charles University in Prague (Czech Republic), (3) University for Teacher Education Lower Austria, Vienna (Austria), (4) Universitat de Barcelona (Spain), (5) University of Helsinky (Finland) and (6) Matej Bel University in Banská Bystrica (Slovakia). Partners have been working on developing and testing new designed chemistry, physics and biology activities for MBL. Other important COMBLAB output is to disseminate activities among school teachers and to create network of teachers using MBL in their teaching practice.

IBSE approach in microcomputer-based laboratory

COMBLAB partners agree with previous researches made on MBL efficacy in science education [e. g. Redish et al. 1997]. Gathered data from sensor projected on screen allow real time visualization of monitored variables. These immediately obtained data in graph skip a need of plotting the data manually. Therefore students have more time for interpretation and analysis that happens often simultaneously with gathering data itself. MBL also enables performing experiments that present variables difficult to observe in traditional arrangement. Generally accepted advantage is a possibility to perform experiments with special time requirements (e. g. long-termed observations in biology or short-termed experiments in physics).

The team of COMBLAB researchers agreed on designing activities involving students in learning process that would make sense and reveal the application of formerly remembered knowledge. At first, the predict-observe-explain (POE) concept was accepted by the team. To emphasize the aspect of students' own impact on designing the experiment in given context, the inquiry based science education (IBSE) approach was implemented as well. IBSE approach is recognized for its efficacy at primary and secondary level when increasing students' interests in learning process and teachers' motivation at the same time and positive impact on students' IT skills and cooperation and communication competencies by working in groups [Barnea et al 2010, Hofstein et al 2005]. This approach can also help to build mental models of chemical phenomena by developing higher-order thinking skills [Aksela 2005].

Methods

Refining didactic sequence

To fulfil the requirement of an inquiry-based biology activity the traditional cook-book instructions were abandoned and the didactic sequence was refined [Šmejkal et al 2013]. The newly developed activities are designed in scheme that can be divided into several parts:

(1) Engagement: at the beginning students are introduced in a situation or relevant context that aims to arouse interest and curiosity (story, problem to solve). From the introduction the 34

initial question arises. First tasks (2 - Warming up) usually relate to students' previous knowledge (counting, variables) and to learn how to use the MBL equipment (purpose of using a particular sensor). After getting know to sensors, students model the real situation, design an experiment according to their suggestions and perform it in a laboratory (3 - Experiment designing and conducting). (4) Drawing final conclusions: when students measure the data they interpret the obtained data or can change the experiment set up if they are not satisfied with the results and make final conclusions that correspond with the data. In the end they (5) communicate the results not just in conclusion, but they have to apply their new knowledge to communicate the conclusions e.g. in email to their friend or in a letter to the magazine that received reader's question.

Implementing, testing, revising

The main authors of six biology activities created according to refined didactic sequence are researchers from Department of teaching and didactics of chemistry (Charles University in Prague). Preliminary versions of activities were prepared and sent for feed-back to partner from Matej Bel University (Slovakia) and to a colleague at the department of biology education, Charles University in Prague. New revised students' worksheets with implemented suggestions were prepared in Czech language, then translated to English and to local languages (Catalan, German, Finnish, Slovak). Prepared biology activities were implemented and tested during autumn 2013 at the department of chemistry of Matej Bel University (Slovakia) with secondary school students from four grammar schools. Implementing and testing in the Czech Republic was carried out in spring 2014 at three Czech grammar schools and with a group of students at the laboratory of department of biology education. The testing brought useful experience that led to creating the re-revised versions of the activities.

Results

Biology activities - students worksheets and teachers guides

Currently, the final versions of six biology activities in Czech and English are available: the activities involve the issue of influencing life conditions - fermentation (Life of yeast), plant topics photosynthesis (Is it safe to sleep in bedroom full of plants?) and germination (Wake up, seed, wake up, it's time to get up!), human issues electrocardiogram (What makes your heart flatter?) and blood pressure (Doctor's assistant), and ecologic issue eutrophication (Plant predators). Parallel to students' worksheets the teachers' versions were prepared: at first, the hints for teachers were coloured in students' versions, finally the teachers' guides consist of part with students version on the left and the commentary part for teachers on the right. Teachers can find there the results of warming up tasks, expected answers, tips for arranging the experiment, tricky parts of the experiment, often mistakes made by students, expected results and specific questions that can be given to students in the end of laboratory lesson to find out whether students understood the activity and the obtained results.

Implementing and testing in the Czech Republic

Two schools from Prague were involved in testing the activities and one secondary grammar school from Moravian town Třinec; in total 5 teachers implemented the biology activities in their laboratory lessons. For evaluation of prepared activities, three evaluating tools were administered to students: before performing the activity students were given a pre-test for motivational orientations and after the activity the post-test for motivational orientations; these tests were adopted from Pintrich at al. [1991] and McAuley at al. [1989]. The third research tool – a COMBLAB questionnaire, was also distributed after performing the activity. It is related to activity itself and brings important feedback on how students perceive each activity, what do they like and dislike the most and other aspects. Detailed information about the concept and evaluating method of used questionnaires can be found in the article of Marek Skoršepa (Matej Bel University) concerning the results from Slovak Republic.

The first author of presented contribution was one of the teachers implementing the activities with first grade students (age 15-16) at Masarykova secondary school of chemistry. Therefore, we want to present some results coming from observation during eight laboratory courses and emerged from discussions with colleague also implementing the activities in four laboratory courses with first grade students.

Regarding students, they got used to work with probeware easily, as they are used to work with notebooks, tablets or smartphones. However, the teacher's help with the software was still needed at the beginning. For about half of the students the concept of the activity was problematic. Despite, it is guided inquiry, the instructions were too vague for somebody and some students did not know how to design the experiment without the teacher's help in a way that would bring reasonable results. Another problem was drawing conclusions: students were rarely able to formulate the conclusions on a paper from comparing the graphs, although when asked by teacher they understood the meaning of the graphs. And when they had to communicate the results, some of them perceive it as useless that could be seen in the level of finally-written letter/e-mail. The context of the activity was well accepted, but rather by younger students than by older ones (comparing with the preliminary teachers' notes from Třinec testing and from last year testing at Masarykova school). Older students seem to prefer shorter introduction because they want to focus on experimenting – this observation needs more research. The design of worksheets was acceptable for students, although it was unusual at the first laboratory. They were able to answer the prediction parts, especially graphs, but mostly with poor verbal description. Their description of the procedure was usually very weak, as it was not reproducible. As sometimes the rewritten results/graphs were not schematic, they were inapplicable for further analysis.

Microcomputer-based laboratory places demands also on teachers. They have to master complex competences: not just soft skills, such as IBSE, facilitating students, managing work without direct instructions, being ready to improvise a lot, but also hard skills such as using the probeware, which means sensors and cooperating software. Furthermore, the teachers have to be ready to solve unexpected technical problems (sensor does not want to connect automatically, the software crashes, etc.). These problems represent an element of uncertainty for teacher that can discourage him/her from MBL usage. On the other hand, it is satisfactory when a teacher sees how students can work independently on precise instructions, how they plan their own work, design the experiment in various ways and develop different competencies than in instructional laboratories. Inquiry approach in MBL also brings opportunity for weaker students, who can for example handle the computer or they surprisingly come with elegant solution of given problem. In all cases, a teacher has to be instantly ready for help and new student's ideas, which is a perfect way for him/her to stay open-minded to scientific thinking.

Conclusion

Six biology activities using IBSE in MBL have been prepared within the project COMBLAB. Despite the subject biology, the issues are exploitable also in other science subjects (or in physical education) that can be supported by the fact that testing of these activities were done by chemistry teachers in lessons of chemistry laboratory with no students objections. At the beginning of implementing inquiry based MBL, there is the obstacle of time: students have to be used to inquiry from previous experiences and they should be able to handle the probeware and software. Solution to this is performing short demonstrational MBL experiments by teacher in the science subjects, when the graph is projected on screen – students get passively familiar with the software interface. More difficult is an acceptance of MBL by the teachers: the initial output takes a lot of teacher's time and energy and the effectivity is not seen at the beginning. Moreover, some technical problems and results that sometimes differ from expected ones bring the element of uncertainty to teaching process that meets teacher's resistance. According to our experience, these factors mostly cause the teachers rejection of using MBL in science. Authors see MBL as an important connection between school and real laboratory work. Therefore, one of the solutions
can be preparing teachers for using MBL during their study in pre-service teaching. Another important aspect of using MBL is the context of experiment, as in real laboratory the instrumental devices are used to solve given problem. If the context of experiment will also make sense to students, their learning becomes meaningful.

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Stratilová Urválková Eva¹, Šmejkal Petr¹, Skoršepa Marek², Teplý Pavel¹,

Tortosa Moreno Montserrat³

¹ Charles University in Prague, Faculty of Science, Prague, Czech Republic,

² Matej Bel University, Banská Bystrica, Slovakia,

³ Universitat Autònoma de Barcelona, Spain

urvalkov@natur.cuni.cz, psmejkal@natur.cuni.cz, Marek.Skorsepa@umb.sk,

pavel.teply@natur.cuni.cz, Montserrat.Tortosa@uab.cat

FREQUENCY OF EXPERIMENTS IN CHEMISTRY EDUCATION

Meliha Zejnilagić-Hajrić, Ines Nuić

Introduction

The importance of experiments in science education is unquestionable. No one doubts their importance in teaching science, because the theory only makes sense - and that is way it can only be learned - if it successfully describes the natural phenomena [Delgado & Gatica, 1997]. Experiments are part of chemistry education for more than 100 years, but their significance in the last 40 years is particularly emphasized [Treagust & Chandrasegaran, 2005; Delgado & Gatica, 1997]. Studies conducted all over the world shown that teachers who had started to perform experiments in teaching chemistry have continued, motivating students' positive reactions [Kolb, 1992]. Studies also showed that there are examples of lack of the experiments in chemistry education in many developed countries. In Germany, for example, research shows that the majority of teachers continue to use outdated system of teaching "ex cathedra" [Eilks, 2002].

Tasks of chemistry education are, among others, development of experimentation skills and ability of observation. These tasks are universal and applicable to every level of education. Instead of lectures and explanations, experiments have to dominate in learning process, as well as observation, creation of conclusions, skills development and understanding [Sikirica, 2003]. Chemistry has to be considered through the demonstration and laboratory work during teaching, so it could fully be understood and appreciated [Bent, 1980].

Practical work in the chemistry education can be divided into several types: experiments that students do, experiments shown to students (demonstration), experiments displayed indirectly (through visual aids), and experiments which are described, verbally or in writing, by the teacher or in the textbook. Experiments that students do should be the priority, while verbally described experiments should include only classical experiments [Achmad, 1975].

Experiments are very popular among students – in one survey [Walton, 2002] large percentage of students agreed that experiments helped them to understand the theory and develop the interest for chemistry, no one said that they are a loss of time - which shows an encouraging link between the experiments and their educational value. There are also critics on the use of demonstrations, making the point that they are time-consuming and often are merely present for entertainment rather than educational reasons of using demonstration in chemistry education [Walton, 2002].

Experiments in Curriculum for 7th grade in Bosnia and Herzegovina

This study was conducted with 7th grade students (eight-year long primary education), because in 7th grade chemistry as a school subject is introduced. Type of performed experiments (prescribed in Curriculum for 7th grade) is mostly demonstration: Separation of mixture ingredients, Physical and chemical changes, Properties of acids and bases and Properties of nonmetals. Situation in schools in Bosnia and Herzegovina is rather inconvenient when it comes to laboratory equipment and chemicals. However, there are experiments that do not require expensive equipment so the lack of equipment cannot always be an excuse.

Methodology

The study was primarily diagnostic. One of the aims was to determine the extent of use of laboratory and demonstration experiments are used in teaching chemistry in 7th grade of selected primary schools. Study included questionnaire for 348 students and nine chemistry teachers from six primary schools in two cantons (counties): SBK (167 students) and KS (181 students) in Federation of Bosnia and Herzegovina. In one canton (KS), the capital Sarajevo is situated. The anonymous questionnaire for students contained 15 items; the questionnaire for teachers 38

contained 16 items. Students' responses were classified by the school they attend and by the canton schools are situated in. Teachers are not classified by schools they teach in.

Results

With this questionnaire we got a considerable amount of data from students, which can be summarized as follows:

Experiments are not sufficiently used in teaching chemistry - only 10.2% students said that teacher performs experiments every time they teach new lesson. More than half of students (59.6%) consider that experiments help them in understanding theory. Some students declared that they had never seen experiment in chemistry.

Majority of students consider experiments necessary: they help in better understanding, easier remembering of theory and make chemistry interesting for learning. This shows that students are aware that experiments are important part of chemistry education.

Students mostly (89.6%) prefer laboratory experiments over demonstration. Only 14.5% students had opportunity to perform experiment by themselves for several times, 15.0% once, while 63.0% stated they had never performed an experiment.

The main reason students cited for the lack of experiments are the lack of specialized chemistry classrooms (49.1%), the lack of laboratory dishes and/or chemicals (52.5%).

Student's responses clearly shows how much are they interested in chemistry experiments, because 85.0% responded that they would like more experiments in chemistry education, and only 8.9% said they are satisfied with the number they already have. The rest of students believe that experiments are unnecessary in chemistry education.

The results gained from questionnaire for teachers show that all teachers agree that experiments are required in chemistry education, and that students are interested in them, but only two teachers said they prepare experimental part each time they teach new lesson. Others said they prepare them when they have the necessary equipment.

The majority of teachers said they partial requirements for experiments, while one of them stated he/she does not have requirements at all but tries to collect the equipment by himself.

In primary school chemistry education teachers mostly demonstrate the experiments. This fact was expected for two reasons – students still do not have needed skills for experimentation, and equipment is not enough for all students or even for groups of students.

Since the insufficient amounts of equipment and chemicals, the fact that teachers rarely organize the laboratory exercises for their students (85.7%) was expected. These responses also indicate a considerable effort and commitment of teachers to provide their students at least a part of experimental work. There was one teacher who does not perform experiments for safety issues.

Conclusion and implications

Many authors and researchers place great emphasis on practical work in chemistry education. Studies conducted all over the world proved the value of experimental work in science education.

This study was caused by unquestionable students' interest for the experiments, and the need to get insight in its frequency our primary schools. We chose students who encounter chemistry as a school subject for the first time.

As expected, students' interest in experiments is great. Teachers also mostly agree regarding the value and necessity of experiments, but common problems like poorly equipped laboratories, insufficient amounts of laboratory equipment and chemicals restrict the use of experiments and therefore reflect on teaching chemistry. What can be done? First of all, we should adequately inform our teachers through seminars and workshops, because there are a number of experiments that can be performed with substances that can easily be obtained (sugar, flour, vinegar...). There is also "chemistry in drops", or micro-scale chemistry, that does not require expensive laboratory equipment and quantities of chemicals are considerably reduced.

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Meliha Zejnilagić-Hajrić, Ines Nuić

Faculty of Science, Zmaja od Bosne

Sarajevo, Bosnia and Herzegovina

mzejnilagic@pmf.unsa.ba; ividovic@pmf.unsa.ba

THE MATTER OF SAFETY IN LABORATORY PROJECTS OF SLOVAKIAN PRE-SERVICE TEACHERS

Csaba Igaz, Miroslav Prokša

Introduction

Chemistry education in Slovakia, and also in other European countries, is moving from a deductive to an inductive approach of teaching [Held, 2011]. The need for providing experiments and applying inquiry is emphasized [Minárechová, 2014]. The expected result of such a shift is an improvement in the level of students' key competences and scientific literacy.

The first requirement of a successful shift toward Inquiry based science education is a teacher, who is familiar not only with the concept of IBSE, but also with other necessary knowledge, which allows him to realize experiments in secondary science education. Such knowledge among other things represents the system of national and international regulations and legislation in terms of the hazardous chemical factors.

In this contribution we list our experiences with the preparation of pre service chemistry teachers for the application of the most important Slovak and European regulations and laws in experiment planning.

Important regulations for safe realization of chemistry experiments

As a reaction of implementing the REGULATION (EC) No 1272/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on classification, labeling and packaging of substances and mixtures ("REGULATION (EC) No 1272/2008", 2013) and also COMMISSION REGULATION (EC) No 790/2009 amending, for the purposes of its adaptation to technical and scientific progress, Regulation (EC) No 1272/2008 of the European Parliament and of the Council on classification, labeling and packaging of substances and mixtures ("Commission Regulation (EC) No 790/2009", 2014) Slovakian parliament issued the "Chemical law", Act NR SR č. 67/2010 Z.z. ("Zákon z 2. februára 2010", 2014), through which the Slovak republic as a member state of the European union gradually implements the regulations concerning chemicals. The act defines hazardous substances and mixtures and refers to the above mentioned regulations No 1272/2008 and No 790/2009.

These regulations above other things list the risk (R) and safety (S) phrases, classification, labeling and concentration limits of substances from Annex I to Directive 67/548/EEC (in charge till June of 2015). They also inform about hazard class and category, pictograms, hazard (H) statements and signal words for given substances (in charge from June of 2015).

Other important regulations in Slovakia are the REGULATION No 286/2004 OF THE GOVERNMENT OF SLOVAK REPUBLIC ("Regulation No 286/2004", 2014) about restricted places and activities for youthful and the REGULATION No 355/2006 OF THE GOVERNMENT OF SLOVAK REPUBLIC (Nariadenie Vlády Slovenskej republiky, 2014) about the concentration limits of hazardous gaseous substances in the air.

According to the REGULATION No 286/2004, children cannot work with substances and mixtures if they are classified as follows: Toxic (T), Very toxic (Tx), Corrosive (C), Explosive (E), Harmful (Xn) if the category is joined with the following R – phrases: R 39, R 40, R 42, R 43, R 45, R 46, R 48, R 60, R 61, Irritant (Xi) if the category is joined with the following R – phrases: R 12, R 42, R 43, carcinogens and mutagens of category 1 and 2. The regulation bans also the use of other substances, for example asbestos and some compounds containing lead.

One moment is particularly important in this regulation: the notion of R and S phrases.

Since this regulation represents the only official document in Slovakia, which allows teachers to determine if a chemical can be used for school experimentation, we also focus on the R and S phrases during pre service teacher preparation and also on the related categorization.

In 2011 the National Institute of Professional Education and the National Institute for Education nominated a team of experts to prepare publications for chemistry teachers to help them in planning chemistry experiments according to the established regulations. The publication of this team [Bartal, Karpatová and co., 2012] represents the best tool in this problem in recent days.

International Chemical Identification	Classification	Labeling	Concentration limits
Hydrochloric acid %	C; R34 Xi; R37	C R: 34-37 S: (1/2-)26-45	C; R34-37: C \geq 25% Xi; R36/37/38: 10% \leq C \leq 25%

Tab. 01. Characteristics of hydrochloric acid according to Regulation no 1272/2008.

Preparation of pre service chemistry teachers at Comenius University

Pre service chemistry teachers during their preparation at the Faculty of Natural Sciences at Comenius University are attending various courses, focusing on practical work in chemical laboratory. The goal of these courses is to master the basic methods of given branches of chemistry, i.e. polarography in analytical chemistry. Students in the sixth semester are taught for the first time to provide chemistry experiments "as teachers". The course, Technique and Didactic of School Experiments in Chemistry, is lead by the Department of Didactics in Science, Psychology and Pedagogy. Three courses (2hours long separately) are devoted to prepare students to provide known demonstrative experiments, alter them, create new experiments or prepare and lead laboratory work of students either trough deductive or inductive approach.

Pre service chemistry teachers on first lessons are taught to be able to find R and S statements in REGULATION No 1272/2008, according to the CAS number of the particular substance, their meaning and the corresponding concentration limits. As a recommended literature we also work with the above mentioned publication of Bartal and co. (2012). Students are taught to determine, if a given substance could be part of an experiment provided by students, or only part of a demonstrational experiment. In this case we work with the REGULATION No 286/2004 and also focus on concentration limits of substances in a solution. The concentration of a solution determines if a mixture is categorized as harmful or not. For example a solution of hydrochloric acid is classified as corrosive, if it contains more than 25% of hydrochloride, it is classified as irritant, if it contains more than 10% but less than 25% of hydrochloride, but it is not harmful, if it contains less than 10% of hydrochloride (see Tab.01). In other words students can work with hydrochloric acid, if it contains less than 10% of hydrochloride, but also if it contains more hydrochloride, up to 25% (according to the Slovak legislation students can work with Irritants, if they are not characterized as R 12, R 42, R 43), if they follow the safety rules, particularly those listed in Tab. 01.

Special lessons are devoted to experiments in which toxic gas is formed. Using these experiments students discuss with the lecturer the concept of limits of hazardous gasses in the air. Students learn to work with the Regulation No 355/2006 and they project their own experiment, which means, that they have to build safe apparatus and calculate the amount of reactants for the production of a given amount of gaseous product, which is within the limit.

Methods

Part of the courses represents constant diagnosis of student's performance, competences and knowledge.

During the courses we apply the following methods:

Observation of student's experimental work during the course; Analysis of laboratory protocols; Analysis of audiotapes of discussions about safety problems; Analysis of short paper pencil test results written at every course; Analysis of the final test results at the end of the term.

Audiotapes were made by the permission of the students.

Protocols are requested from students, where they must list R_{-} , S_{-} phrases and H_{-} statements. They must also explain the meaning of these phrases from a practical point of view, i.e. if the substance can be part of an experiment provided by students, or only part of a demonstrational one, if the chemical waste can be poured to the sink, or must be collected as hazardous etc.

Results

The analysis of recorded discussions, created during the second course (there are three courses) reveals, that students do not use the recommended literature when they are seeking for the risk and safety phrases, they just "Google". According to the references in their laboratory protocols, the most frequent source for them is Wikipedia, but some students search on web pages of providers or suppliers of chemicals, for example Sigma – Aldrich, or smaller local corporations. Students in laboratory protocols list these statements and write a short, necessary comment about them, but many times the comment does not involve all aspects of safe realization of experiments. Furthermore students do not understand, or realize the meaning of some phrases. Observation of their work in the laboratory reveals, that most of the students would pour dangerous chemicals to the sink, even if they know the classification of the substance or mixture and the corresponding R - and S - phrases. A typical example represents the solution of potassium permanganate, which is used in several experiments during the whole course and students had to list the phrases several times in their protocols during the year. Despite of this, students do not realize that this substance represents danger to the environment, and cannot be poured to the sink when liquidating chemical waste. We emphasized several times this problem during tidving up the laboratory. The results of the final test at the end of the term indicates that this step, i.e. pointing out this problem and discussing about it lead to the realization that manganese should be reduced to oxidation state 4 or 2 before pouring to the sink. Controlling the protocols and writing comments by the lecturer does not brought the same result.

Other analysis reveals that students are familiar with the concentration limits of substances in solutions so they are able to determine if a given experiment should be a demonstration or it can be also a laboratory work. They list these details in laboratory protocols but can also defend their opinion during discussions about school experimenting.

On the other hand students do not understand the concept of concentration limits of hazardous substances in the air. They do not know, what does it mean to have $0,5 \text{ cm}^3$ of a given gas in 1 m^3 of air (the limit for SO, in the air in regulation no 355/2006).

For solving this problem, we decided to ask student to project safe experiment, for demonstrating the bleaching effect of sulfur dioxide. The observation of students work and analysis of recorded discussion reveals, that students have problem to design safe apparatus for producing hazardous gaseous products: they do not realize the growing pressure during gas production. To ensure, that the gas can not get out from the apparatus, students often design closed ones. The do not realize that the pressure would rise inside, until the apparatus explodes. Students also have problem to calculate the amount of reactants for producing gaseous product of a given volume. Projecting the experiment allows for diagnose all the problems students have,

what is emanating from lack of experience. Discussion between students and the lecturer leads to realizing these problems and finding a solution. Students understood the concept of concentration limits of hazardous substances in the air; they connected it with particular substance and limits, expressed by the maximal volume of substance in a given amount of air.

Conclusions and implications

In this contribution we focused on experiences with teaching the application of basic national and international regulations and legislation for Slovakian pre service chemistry teachers. These regulations mean practical implications for every chemistry teacher not just in Slovakia, but also in every country, which adopt the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

Based on the results of the diagnosis of students theoretical and practical knowledge and ability, we can conclude as follows:

The proper methods for teaching the concept of concentration limits of chemicals in solutions are proved to be talking about alternatives of a given experiment during the course and requiring alternatives of a given experiment in the laboratory protocol.

The proper method for teaching the concept of concentration limits of hazardous chemicals in the air, according to our experiences, is designing experiments for producing hazardous gas products (for example SO_2). Students realize the concept of concentration limits of hazardous chemicals in the air; they get motivated to use the regulations, because they see the meaning of them. As an additional, not expected result is, that students realize misconceptions about building apparatus for gas production, and they learn to construct such apparatus. Students also realize the necessity of, and motivated to understanding calculus, which enables to determine the amount of produced hazardous gaseous product.

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Csaba Igaz, Miroslav Prokša

Department of Didactics in Science, Comenius University in Bratislava, SL

igaz.cs@gmail.com, proksa@fns.uniba.sk

VARIOUS EXPERIMENT TECHNIQUES AS SEEN BY STUDENTS

Małgorzata Nodzyńska

Background, framework and purpose

As far as from the 19th century laboratory tests were considered a fundamental method of teaching of chemistry on all levels of education [Burewicz, Wolski & Jagodziński, 2008]. It stems from the fact that in the period of the biggest development of natural sciences, they were based mainly on the empirical process of cognition. This is why it was assumed that the process of education in natural sciences (including chemistry) should reflect the cognitive process of a scientist and it should be related with research conducted both by teachers and pupils [Bergandy, 1997]. Also nowadays [Pietruszewska, 1985] it is still believed that the process of chemical education should resemble a course of a scientific research. For this reason, those methods are considered as the most valuable in which the learning process is done by discovering, including laboratory tests and experiments [Soczewka, 1975]. This belief is supported by the results of the research conducted [Kłoczko, 1978; Matysik, 1971; Nędzyński, 1986].

Also many psychological and pedagogical theories are in favour of this manner of thinking (e.g. the progressive school of J. Dewey [1929], or the active school supported by W.A.Lay, E.Claperede, C. Kerschensteine). Also the learning pyramid by E. Dale supports the concept of teaching chemistry by acting – that is by carrying out experiments.



Fig. 01. The learning pyramid by E. Dale.

In chemistry didactics one distinguishes a chemical test, which is a series of technical activities leading to a particular outcome, from a chemical experiment, which apart from performing manual activities requires also from an experimenter an intellectual background and the ability to use the test results [Soczewka, 1975]. This is why in order to make the future chemistry teachers only plan and carry out experiments on their own but also teach this art to their pupils, as a part of the course "Designing chemical experiments" students get acquainted with the theory of experiments planning and design (DOE) and they get to know various techniques of conducting and presenting experiments. The main aim of those classes is to teach students methods and techniques of experiment planning and design, but simultaneously students learn different forms of both conducting and presenting the experiments. The ability to choose a correct technique of experiments and tests presentation is useful for students not only during classes on methods of chemistry or biology teaching, but also it gives the possibility of a correct presentation of one's research in articles or MA theses.

This article shall discuss research results that concern uniquely the application of various techniques of chemical experiments presentation.

In the course of laboratory classes students are asked to design and carry out simple chemical experiments with the use of the DOE theory and selected experiment techniques. Students submit for acceptance their own plan of an experiment to the lecturer and having conducted the experiment, they write a final report.

During first laboratory classes, students perform the experiments planned while applying classical laboratory methods. On the following classes, while planning their experiments students should plan them in such a way as to make it possible to conduct them using given research techniques or tools. During the next classes, students plan and conduct experiments with the use of:

- the micro-scale technique [Skinner, 1997; Winter & Russo, 1998; Kazubski & al., 2008];
 the paper chromatography [Marczenko & Minczewski, 2001; Rosołowski, 1993];
- the projection of experiments in transmitted or reflected light with the use of slide projector or presenter etc. [Nedzyński 1964, 1965, 1986, 1992; Patriak & al., 1996];
- a microscope connected to a computer that allows for both taking pictures and making videos;
- sets of sensors connected to a computer (e.g. the Vernier system) [Bilek 1994,2001a,2001b, 2007];

 films [Trinklein 1966; Fickert 1976; Cieśla & Paśko 2006; Paśko & Rogowicz-Czochra 2008; Jagodziński & Wolski, 2012];

- on-line laboratories [Moroń & Nodzyńska 2004; Nodzyńska & Paśko 2007];
- microwave [Šulcová & Nývltová, 2004a, 2004b; Šulcová & all 2007a, 2007b, 2009];
- presentations [Nodzyńska, 2012];
- educative trips [Nodzyńska, 2005, 2009; Grzechynka & inni, 2005; Nodzyńska & Bilek 2009].

Methods

47 students of the first year of post bachelor master's studies with the speciality "Biology with chemistry teaching" took part in a hybrid course supported by the Moodle platform. There were both students from full-time studies (24 people) and extra-mural (23 people). No differences were found between answers of the two groups of students. The research covered the years 2012/2013 and 2013/2014. No differences were noticed between the subsequent years of students. The course covered 10 hours of lectures and 30 hours of laboratory classes (10 meetings of 3 hours each). For all those activities on the platform of remote teaching/learning, one could find additional materials, theoretical and practical information, links to web pages, books, examples of experiments and techniques, sample reports as well as surveys, tool for submitting homework and work and safety rules.

Throughout the duration of the course, students were supposed to regularly answer the surveys concerning individual experiments techniques. Their task was to relate to:

- their comprehension of the task instruction and a sample experiment,
- the level of difficulty of adaptation of a traditional experiment for a given laboratory technique,
- interest in a given technique in comparison with a traditional laboratory method,
- the level of difficulty while conducting the experiment.

In order to construct the survey a Google.doc tool, with which students have had previous contact, was used. Each questionnaire evaluating individual techniques consisted of 7 questions: 3 multiple-choice ones and 4 open ones.

After the completion of the course, students with the use of the "Vote" option on the Moodle platform chose:

- the most interesting,
- the easiest to perform,
- the most difficult to perform experiment technique.

After the course end, an analysis of documents was conducted, which covered among others:

- the number of log-ins to particular course sections;
- grades of individual students and average grades;
- grades of individual final reports and their means.

Results

Answers to individual questions depended on the technique chosen.

While evaluating the classical micro-scale 50% of students taking part in the research claimed that experiments conducted with this technique are more interesting than experiments conducted with the traditional method but also 50% of respondents were of the opposite opinion. It can be said that this method interested students. All students taking part in the research understood the description of a sample experiment carried out with the use of this technique. Also none of the students had problems with the adaptation of a classical experiment selected by themselves to the micro-scale. Among the advantages of the classical micro-scale in experimenting, students mentioned above other:

• the economy of reagents and thus costs of conducting experiments;

• faster time of observing the reaction – which translates into the possibility of conducting a larger number of individual tests and as a result a wider study of the problem;

• security – with small amounts of reagents even very caustic or toxic substances are not that hazardous;

• the possibility of using one's creativity for example by replacing a ready-made traditional laboratory tools with own-made constructions.

Among the negative aspects of this technique, students mentioned above other:

• the necessity of extreme precision – it is enough to make an error by 1 drop to completely change the outcome of an experiment;

• poor visibility – in order to observe changes everyone needs to conduct the experiment on their own, this technique cannot be used as a show;

- heating with the use of candles takes too much time;
- not every reaction is sensitive enough to make its results observable in the micro-scale.

It also turned out that what was an advantage of this method for some students, for others was a drawback – students mentioned small availability of appropriate glass for the micro-scale and the necessity of constructing it on their own.

While comparing the experiment conducted with the usage of classical techniques with an experiment in the micro-scale, students mentioned the following advantages:

• repetitiveness of results (despite the fact that the students' task was to design an experiment of their own, they often turned to well-known tests modifying only the conditions of the reaction – so that the "basic" recipe for the experiment carried out traditionally was well-described unlike the modification to the micro-scale technique);

- one does not have to follow precisely defined proportions (quite a controversial approach when it comes to certain types of reactions);
- the possibility of getting pupils acquainted with the tools in a chemical laboratory;
- the effect of the test may be better visible due to bigger amounts of reagents.

Students mentioned the following drawbacks of classical techniques in comparison to the micro-scale:

- a large amount of chemical reagents used;
- danger (for example while heating caustic or toxic substances);
- small creativity in using the laboratory tools;
- a long time required to conduct experiments with this method.

Students pointed also to the fact that schools often lack traditional laboratory tools necessary to conduct this type of experiments.

The paper chromatography micro-scale appealed to students much more. 72% of students taking part in the research said that experiments carried out with this technique are more interesting than experiments conducted with the use of traditional methods, 22% of respondents did not have any opinion about this subject. Only 6% of respondents did not like this technique of conducting experiments. It can be said then that this method aroused interest among students. Also all students taking part in the research understood the description of a sample experiment carried out with the use of this technique. However 11% of students had problems with adapting a selected classical experiment to the paper chromatography micro-scale. It can be said then that this technique turned out a bit more difficult than the traditional micro-scale. Among the advantages of the paper chromatography micro-scale in experimenting, students mentioned among others:

- economy of reagents;
- safety, even if caustic or flammable substances are used;
- the rapidity of conducting experiments;
- the experiment outcome is clearly visible.

Students also pointed to the fact that they can be performed in a school chemical laboratory.

Among the negative aspects of this technique, students mentioned above other:

• not all the experiments can be conducted in such a way (e.g. it concerns reactions where heating up is necessary);

• we have to stick to a defined number of "drops";

• poor visibility – each observer has to come closer to the person conducting the experiment to be able to see anything;

- lack of appropriate equipment, e.g. ceramic tiles;
- sometimes it is difficult to see the effects of an experiment (e.g. dissolution of a sediment);
- the reactions carried out must be sensitive due to a small amount of reagents used;
- the outcome of experiments is slightly less visible.

While comparing the experiment conducted with the use of classical techniques to an experiment with the use of paper chromatography micro-scale, among advantages students mentioned above other:

- the description of experiments with the use of traditional techniques can be found on the Internet;
- simple manner of performance;
- everyone sees the course of the experiment and its stages;
- the possibility of getting to know the chemical laboratory equipment.

On the other hand, among the drawbacks of classical techniques in comparison to the paper chromatography micro-scale, students mentioned:

- larger amounts of reagents used;
- it is necessary to have more space to conduct traditional experiments;

• experiments conducted classically are not as interesting as those conducted in an original/ new way – pupils usually know the traditional tests;

- long time necessary to conduct experiments;
- a bigger number of laboratory equipment is necessary, for example laboratory glass;
- the experiments do not always "work."

Another technique of conducting experiments with which students were made acquainted was the usage of a slide projector. As many as 81% of students taking part in the research considered this technique of presenting experiment results to be interesting. 19% of respondents said that they had no particular opinion on this subject. None of the students disliked this technique of conducting experiments. It can be said then that this method was definitely liked by the students. Also all students taking part in the research understood the description of a sample experiment carried out with the use of this technique. However 6% of students had problems with adapting a selected classical experiment so as to be able to use a slide projector. However it does not fully render the difficulty of the technique – some (ca. 20%) experiments planned by students

did not give expected the results. It can be said then that this technique turned out to be difficult for students. Among advantages of of the usage of a slide projector in experimenting, students mentioned among others:

• the possibility of presenting the experiment being conducted to a larger group of people at the same time, the experiment is equally visible to all the observers;

- colour reactions taking part in water solutions can be easily shown;
- the course of the reaction is easily observable;
- the possibility of observing e.g. movement (diffusion, sedimentation, secretion of gas bubbles);

• the majority of reactions conducted with the use of this technique look very interesting and unusual, equally fascinating are pictures of reactions conducted with this technique;

• the possibility of simultaneous setting on a slide projector several parallel tests as a part of one experiment (e.g. with different concentrations of solutions and comparison of the results).

Among the negative aspects of this technique, students mentioned above other:

- the slide projector heats up quickly (which influences the speed of reaction);
- substrates cannot be heated to a temperature higher than the slide projector temperature (ca. 60°C);
- sometimes the slide projector distorts the image;
- not in every case the course/ outcome of the experiment is visible on the slide projector screen;

• the colours presented are not always correct (intensive colours of substances being created are seen as black on the slide projector);

- not all the tests can be presented with the use of a slide projector;
- the classroom must be partially dark;
- one has to have a slide projector.

It turned out that even if the restrictions of a slide projector are known, it is not always predictable how a given experiment will be presented on the slide projector. Sometimes a visual effect depended on the concentration of a substance and the speed of the reaction (for example a fast secretion of gas bubbles blurred the image of the reaction's course).

While comparing the experiment conducted with the usage of classical techniques with an experiment with the use of a slide projector, students mentioned the following advantages of classical techniques:

- a better image, not distorted;
- pupils are eyewitnesses of the course of experiment;

• repetitiveness of the outcome related to the fact that descriptions of classical experiments are easily available;

- all experiments can be carried out in the "classical" manner, without any restrictions as to the temperature of reaction and the shape of vessels;
- one can conduct exothermic reactions;

• in this way any quantitative and qualitative reactions can be carried out, one does not have to have specialistic equipment (a slide projector) and know how to use it.

It seems that students were not totally truthful. At the Moodle platform students were given a link to an e-book describing tests and experiments with the use of a slide projector [Patriak & al. 1996], they were also given additional literature [Nędzyński 1964; 1965; 1986; 1992] that describes how to conduct this type of experiments; this is why it seems that the complains about the lack of ready-made descriptions of this type of experiments is not true – especially that ready-made experiments with the use of a slide projector outnumber the descriptions of the paper chromatography micro-scale. Also the difficulties relating to the usage of a slide projector seem to be much exaggerated.

On the other hand, among the drawbacks of classical techniques in comparison to experiments conducted with the use of a slide projector, students mentioned:

- large amounts of reagents are used;
- worse observation of the course of reaction, less visible for a larger number of people, photos

are less spectacular.

They also often pointed to the lack of the motivating aspects of traditional tests / experiments by writing:

• in some cases traditional tests may be boring for pupils;

• they are not as interesting as those conducted in an "original" manner and usually they are already known to pupils.

It seems then that the usage of a different technique to show experiments at school should make pupils more interested in chemistry.

There were also some voices claiming that a presentation with the use of a slide projector is safer than a direct observation:

• when we want to show pupils an experiment for example at the laboratory table we must take into account the fact that it will be crowded around the table so if hazardous substances are used, there is a risk of danger.

Another technique of showing experiments (a microscope connected to a computer and a overhead projector) was very well-known among students but from biology classes – it was the first time that they had to use it during chemical experiments. 79% of students taking part in the research considered this technique of presenting experiment results to be interesting. 21% of respondents said that they had no particular opinion on this subject. None of the students disliked this technique of conducting experiments. It can be said then that this method was liked by the students. Also all students taking part in the research understood the description of a sample experiment carried out with the use of this technique. However 7% of students found it difficult to design their own experiment with the use of this technique. While conducting the experiment itself, it turned out that help from the lecturer is necessary for example to select the size of metal swarf, concentration of solutions, etc.

Students were fascinated with the usage of the well-known equipment to a new field – chemical experiments. Among the advantages of using a microscope connected to a computer and overhead projector, students mainly mentioned visual effects:

• experiments conducted on a cover glass are usually very striking;

• the possibility of observing the undergoing reaction with a big magnification, which gives us the possibility to follow the course of reaction when at this stage we would notice no changes just with our eyes;

- outlook on the reaction from a different perspective;
- an interesting image crystalline structures are visible;
- amazing effects (size and shapes of crystals);
- one can notice the crystalline structure of a substance or sediment;
- the possibility of having a closer look at the results of the test;
- more interesting observation on the micro-world level;
- the undergoing processes can be seen with a higher precision;
- a very striking observation of the reaction in magnification.

Extremely rarely in comparison with previously described techniques, voices concerning the economy of reagents while using this technique or work and safety rules were mentioned.

In the context of teaching nature sciences, the following opinions were voiced:

• pupils have an opportunity to use a microscope during a subject different than biology, and additionally learn its elements and how to use it.

Most frequently, as a negative feature of this method students mentioned:

• price (which is not true – during classes students used an educative version of a microscope that costs about PLN 250);

• poor quality of photos or films (with this price of a microscope it is unfortunately true).

Students pointed also to the following facts:

• only specific experiments can be conducted with the use of a microscope (e.g. it is difficult to change temperature in the experiment);

• not in every case the course of the experiment and its final outcome will be visible under the microscope;

• precision is required while preparing the experiment;

• one has to be cautious not to damage the microscope;

• experiments carried out with the use of a microscope take time (it is true – these were the only classes when students did not have enough time).

While comparing the experiment conducted with the usage of classical techniques with an experiment with the use of a microscope, students mentioned the following advantages of classical techniques:

• recipes for traditional experiments are tested - lack of such recipes for experiments with the use of a microscope;

- repetitiveness of the results obtained (due to the verified character of recipes);
- one does not have to follow tightly / precisely a pre-defined proportions;
- those experiments are applicable in quantitative and qualitative chemistry;
- better availability and lower price of the traditional equipment;
- a microscope is not required.

As it can be noted students would be most eager to carry out those tests / experiments that they already know and in such a way that does not require high precision.

On the other hand, among the drawbacks of classical techniques in comparison to experiments conducted with the use of a microscope, students mentioned:

• one cannot see precisely the behaviour of different substances during a chemical reaction, one can observe only large crystals with the naked eye;

• "waste" of reagents.

Another technique of conducting experiments that students were made acquainted with was the usage of sensors connected to a computer (the Vernier system). 62% of students taking part in the research considered this technique as more interesting than the traditional manner of conducting experiments, 21% of respondents said that they do not have any particular opinion on this subject, and 15% decided that the classical experiments are more interesting. It can be said then that this method was not particularly liked by the students. Not all of the students taking part in the research understood the description of a sample experiment carried out with the usage of this technique, as many as 15% of students found it difficult to comprehend the sample instructions given, and as many as 23% of students found it difficult to adapt a selected classical experiment so as to make it possible to use Vernier sets. It seems to be highly incomprehensible taking into consideration the fact that during physical chemistry or instrumental analysis classes, students carried out similar experiments with the use of much more advanced equipments. Perhaps, the problem was that it was the first time that they were supposed to design an experiment on their own, and not just conduct the test basing on a ready-made instruction.

Despite the fact that some students considered this technique of conducting experiments as difficult, they noticed its numerous advantages. Among the advantages of using the Vernier sets in conducting experiments, students mentioned above other:

- the possibility of automatic registration of the measurements on the computer;
- the possibility of a precise measurement, examination of those elements of a given process which are not visible with the naked eye;
- the precision of measurements made;
- the possibility of observing the results on a computer screen;
- faster conduction of experiments as well as easy and simple reception and registration of results, which is ensured by connecting the Vernier sets to a computer.

The automation of registration of the results significantly influenced the pace of carrying out the experiments.

Despite the fact that students were not asked about the advantages of the Vernier system in the education – some advantages they mentioned related to the didactic aspect:

• experiments with the use of the Vernier system are interesting – pupils have an opportunity to make individual measurements in a simple manner that does not require the ability to use professional laboratory equipment;

• an opportunity for pupils with a new / unknown equipment.

Among the drawbacks of the usage of the Vernier sets to conduct experiments, students mentioned above other:

- difficulties in operating the equipment (the manual was available only in English);
- it was necessary to learn how to use the software accompanying the measurement tools;
- costs of the equipment;

• the results of measurements are not always correct (it stemmed from the lack of knowledge how to use the equipment – students did not calibrate the equipment before using it);

• the equipment has to be handled with care.

It can be said then that despite the fact that the students have used a more advanced equipment during previous classes - in a situation where they were supposed to prepare the equipment for research, calibrate it and make measurements on their own and without a detailed instruction what to do and in what order - it turned out to be too difficult for them.

While comparing the experiment conducted with the usage of classical techniques with an experiment with the use of the Vernier system, students mentioned the following advantages of classical techniques:

- repetitiveness their descriptions are easily available and precise;
- one can get to know the traditional laboratory equipment;
- one does not have to buy special equipment;

• the experiments may be carried out without being stressed that if they damage something, they will have to pay a lot of money

It can be noticed that the students are attached to what they already know –the traditional equipment – not taking into consideration the fact that it also costs a lot (the cost of a traditional thermometer is comparable to the cost of a thermometer in the Vernier system).

On the other hand, among the drawbacks of classical techniques in comparison to experiments conducted with the use of the Vernier system, students mentioned:

- constant "surveillance" over the system;
- data have to be noted down on one's own;
- diagrams have to be drawn on one's own;
- measurements are not that precise;
- experiments take a lot of time;
- monotony;
- considerable amount of laboratory equipment is required;
- expensive / professional equipment it is a risky thing to do something on one's own...

It can be said that students like the most automation of their work and replacement of boring, monotonous actions with a computer.

Another technique of presenting experiments with which students were made acquainted was the usage of ready made films. Students were supposed to find educative films on the Internet, on CDs attached to course-books. Students' opinions for and against this technique were not evenly distributed. It can be said then that students did not particularly liked the method – the main argument against it was the fact that only few films can be considered as experiments – the

majority of films were merely presentations. It can be concluded that the films available on the market do not meet requirements for an experiment and cannot be used for this purpose. All students taking part in the research understood the description of a sample experiment conducted with this method, none of the students changed anything in the film they found.

Among the advantages of using films in teaching chemistry, students mentioned:

- the possibility of using it when there are no reagents or laboratory equipment at school,
- films are easily available on the Internet.

On the other hand, the main argument against using films was the fact that they do not develop manual and intellectual skills among pupils. Students said also that despite a large number of films on the Internet, they hardly ever show real chemical experiments with several variables – usually they are simple tests.

While comparing experiments performed traditionally with those seen in films, students thought that the biggest advantage of traditional experiments its the possibility of observing the results of experiments on live by pupils and their contact with the laboratory equipment.

Students were also acquainted with the possibility of conducting chemical experiments in on-line laboratories. 25% of students taking part in the research said that this technique is more interesting than traditional experiments, whereas other 25% of students considered this technique as less interesting, 50% has no opinion on this subject. Only 17% of students taking part in the research found it difficult to design their own experiment in an on-line laboratory.

None of the students found it difficult to understand the instructions prepared for them. Among the positive aspects of conducting experiments with the use of on-line laboratories, students usually mentioned:

• experiments can be conducted in all space conditions (one needs only a computer and Internet connection);

- one does not have to buy reagents and laboratory equipment, which leads to savings;
- different experiments can be carried out even if there are no good conditions for doing so (group of pupils is too numerous, lack of fume cupboard, reagents have too high concentration);
- pupils can practice their foreign language skills;
- on-line experiments may be an alternative to a traditional homework;
- free, easily available, safe;
- it is possible to safely and rapidly conduct many tests that is an experiments with a change of many factors;

• pupils have the opportunity of carrying out experiments on their own, which is not often possible at school during chemistry lessons. Pupils can conduct experiments on their own on the computer.

Equally frequently, students mentioned drawbacks of on-line laboratories:

• small number of on-line laboratories available without the requirement of the registration in a service;

• an on-line laboratory does not render the actual feeling that arises while carrying out real experiments; not everything can be seen with the naked eye and felt – lack of feelings, lack of emotions that accompany working with the real chemistry;

- Internet access and installation of special software is required;
- lack of contact with the real laboratory equipment and reagents;
- lack of on-line laboratories in Polish.

While comparing the work in a traditional laboratory to the virtual one, students enumerated the following advantages of the traditional laboratory:

• pupils have contact with real reagents, acquiring thus valuable skills;

• the results are clearly visible – students see the course of the experiment in real time (we see and hear everything, we can touch and smell);

• we can see the course of reactions, not only their results, and sometimes even feel more or less 54

pleasant smells;

- the opportunity of getting acquainted with the laboratory equipment;
- one can play with the equipment, etc.

While comparing the work in a traditional laboratory to the virtual one, students enumerated the following disadvantages of the traditional laboratory:

• fact that at school it is often only the teacher who performs the experiments with the use of traditional method, pupils rarely conduct them on their own;

• traditional experiments undoubtedly take much more time than those done on-line;

• not all experiments can be carried out in the traditional way, for example due to safety rules, the number of pupils in a given class or lack of reagents;

• large consumption of reagents - which increases the costs;

• traditional experiments are not as interesting as those carried out in a "new" way and are usually known to pupils.

Summing up, it can be said that students mainly liked the speed and safety of conducting on-line experiments, whereas they think that experiments conducted in such a way kill the spirit of chemistry – taking away from pupils the emotions that accompany conducting experiments on one's own.

Another technique applied to conduct experiments with which students were acquainted was the use of a microwave oven. 62% of students taking part in the research decided that this method of presenting experiment results is more interesting that conducting experiments in the traditional manner, 23% of respondents did not have any opinion on this subject, and 15% said that classical experiments are more exciting. It can be said then that this method was not particularly liked by the students. Not all of the students understood the description of an experiment carried out with the use of this method, 8% found it difficult to comprehend sample instructions given (despite the fact that they were given only in English and Czech). None of the students had problems with adapting a selected classical experiment so that as to use a microwave oven. It seems that it results from the fact that these were already the 8th classes during which they were supposed to design an experiment on their own, and not make a test on a basis of a ready-made instruction.

Among the advantages of the usage of a microwave oven in comparison to traditional experiments, students mentioned:

- it is a innovative solution and the usage of a new equipment that may arouse pupils' interest;
- faster time of conducting the experiment one can save time during the lesson;
- microwaves are easily available;
- pupils do not have direct contact with boiling substances;
- sometimes instead of highly concentrated substances (e.g. acids) their weak solutions are sufficient higher level of safety;
- it is a method that "imposes" creative thinking.

However, despite the fact that in the majority of cases students positively evaluated experiments conducted with the use of a microwave, they also pointed to some drawbacks of this method:

• a microwave heats the reactive substance up in an uncontrolled manner which is why the experiment has to be supervised all the time because through the glass it is not very well visible what is going on inside;

• the course of the reaction is not visible for pupils – we put something in and take it out when it is over, pupils do not have the opportunity to observe the undergoing changes;

- it heats up very quickly and needs constant surveillance;
- not every school laboratory is equipped with a microwave;
- potential danger, e.g. ignition of a substance in the microwave;
- a microwave can be easily damaged.

While comparing the experiment conducted with the usage of classical techniques with an experiment with the use of a microwave oven, students mentioned the following advantages of classical techniques:

• the results of reactions in traditional experiments are very visible – everything can be observed and controlled systematically (including heating up of the system);

- in traditional experiments we see and hear everything, we can touch and smell;
- descriptions of traditional experiments are easily available.

• contact with the laboratory equipment.

On the other hand, while comparing the experiment conducted with the usage of classical techniques with an experiment with the use of a microwave, students mentioned the following drawbacks of classical techniques:

• traditional experiments take more time;

• they are not as interesting as those conducted in an "original" manner and usually they are already known to pupils.

• heating up on a burner may be risky.

It can be said then that for students the biggest advantage of performing experiments in a microwave oven is a short time of experiment – and the biggest drawback – the impossibility of direct observation of the undergoing changes.

Another technique of presenting experiments – a presentation – was usually very well-known to students, for example from presentations prepared by themselves (e.g. for the University Open-Door Days, Festival of Sciences, University of Children and Parents). 92% of students taking part in the research considered this technique of presenting experiment results to be interesting. Only 8% of respondents disliked this technique of conducting experiments.

It can be said then that this method was liked by the students - probably the high evaluation of this technique stems from the fact that presentation prepared by students resembled more theatre shows.

Also all students taking part in the research understood the description of a sample experiment carried out with the use of this technique. However, 8% of students had problems with designing their own experiment with the use of this technique (these were the same students who disliked the method).

Among the advantages of the usage of a presentation in comparison to traditional experiments, students mentioned:

- they are spectacular they can be shown in a "macro-scale" in front of a large audience;
- experiments shown in such a way are more intriguing and arouse popular interest;
- visible for a large number of people;
- presentations are something unusual, amazing;
- presentation create conditions for learning through playing;
- presentations are usually very striking and they stimulate pupils' imagination.

On the other hand, among the drawbacks of a presentation in comparison to classical techniques, students mentioned:

- they have to be carefully prepared and rehearsed;
- they require special conditions;
- they are not always safe to be carried out;
- their results do not always live up to our expectations;
- it does not fully pass on knowledge;

• we have to carry them out in such a way so that everybody sees what is going on (e.g. in a beaker instead of in a test tube).

It is quite surprising that as a drawback students mention the necessity of thorough preparation and rehearsal of experiments carried out as presentations – it seems that the necessity of thorough preparation and rehearsal applies to all kinds and types of experiments, not only to presentations.

While comparing the experiment conducted with the usage of classical techniques with an experiment with the use of a presentation, students mentioned the following advantages of classical techniques:

- smaller amounts of reagents are necessary for classical experiments;
- they develop knowledge and skills;
- smaller risk of an accident;

• traditional experiments are thoroughly verified and that is why they more often bring the expected results.

While comparing the experiment conducted with the usage of classical techniques with an experiment with the a presentation, students mentioned the following disadvantages of classical techniques:

- the classical experiments are not that stunning;
- experiments carried out with the traditional method do not arise so much interest among pupils.

The last technique under examination were educative trips combined with experiments. This technique was the most appreciated one among all the techniques / methods of conducting experiments by students – perhaps it was because it included going out of the laboratory into an open space. All students taking part in the research said that they liked this method and that they understood the instructions. Only 4% of respondents claimed to have difficulties with preparing their own experiments for educative trips.

Among positive negative aspects of this technique, students mentioned above other:

- it makes it possible do discover phenomena and processes occurring in nature;
- it widens the scope of observations;
- it is more interesting than a traditional lesson.

The main disadvantage of this method are organisational difficulties.

The students also pointed to the fact that it is difficult to compare the traditional techniques of conducting experiments to experiments carried out during a trip.

After the completion of the course, students, using the "Vote" module on the Moodle platform, were supposed to choose the most interesting, the easiest to perform, and the most difficult to perform method of conducting experiments. Looking from the absolute value point of view students chose the technique of presentation as the most interesting method of showing an experiment (100%) – not taking into account the fact that this technique is not particularly applicable for showing several consecutive tests with different parameters – which is a rudiment assumption of the experiment. While selecting the technique the easiest to perform students pointed to the micro-scale (78%) and trips (20%). Indeed, while using these methods in the majority of cases, the experiments presented by students were identical to the classical, easily available and well-described tests.

Vernier, microscope, and microwave were mentioned as the most difficult techniques – that is techniques for which the descriptions of tests were not easily available, which means that the preparation of an experiment by students required much more work and creativity.

After the course end, an analysis of documents was conducted, which covered among others: • the number of log-ins to particular course sections;

- grades of individual students and average grades;
- grades of individual final reports and their means.

Generally speaking it can be stated that the interest in course was much bigger than it was initially assumed. What was very frequent was the prolongation of classes by the students ("because I still need to check something"), talking about classes with the lecturer at any given opportunity, very thorough and detailed preparation of reports on the classes. Also the virtual part of the course was popular among the students. They logged in the Moodle platform not only before a given classes – in order to prepare for the classes, or after the classes to submit a report – they also logged in between those dates, sometimes going back to classes that have already taken place, and sometimes going forward to the classes that were still to come. Students also logged in to the theoretical part (lectures), even when it was not required from them (because for example they were present on the lecture). The average time of logging-in of students was 22h – which corresponds to the half of their obligatory classes (15h of lectures + 30h of laboratory classes). Students' involvement in work translated into very high grades. The average grade was 4,75, and the lowest one – 4. The majority of students were given 5 as their final grade.

Conclusions and implications

The research results show that all students understood the instructions concerning the description of a given technique. The majority of them had no problems with the adaptation of a traditional experiment to an experiment conducted with the selected technique. Also the majority of students thought that a traditional experiment is less interesting than an experiment with the use of a different technique. In the majority of cases new techniques did not render students' work more difficult. Despite this fact, students enumerated many drawbacks of the newly acquired techniques of experimenting and they thought that they are applicable only in particular situations as opposed to the traditional work in a laboratory.

The results gathered are not unambiguous. On the one hand students think that the newly learnt techniques are attractive and may arouse pupils' interest, and also allow for conducting the same tests in different ways (which may be important when we consider a small amount of reagents at school). On the other hand, students see numerous limitations of these methods, which discourage them from applying the newly learnt techniques. It seems that the majority of students represent reluctance to the new, especially that the descriptions of traditional tests are available, and there are not so many of them for the new techniques and they are not so detailed.

It can be stated that in general students are characterised by reluctance to the new and the desire to carry out tests according to ready-made instructions. It does not give a good image of their creativity. However, during their laboratory classes, students were eager to work, showing great creativity. It can be concluded then that students have the potential to be creative – however it must be awakened in them. This is why laboratory classes that force students to work on their own from planning the experiment, through its conduction and description seem to be a necessary element of education.

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Małgorzata Nodzyńska

Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

EVALUATION OF THE USE OF NATURAL USER INTERFACE TECHNOLOGY TO CREATE A VIRTUAL CHEMICAL LABORATORY

Piotr Jagodziński, Robert Wolski

Introduction

In the natural sciences such as chemistry, physics, biology and geography, it is important to carry out experiments either in the laboratory or outdoors. In this respect, experimental chemistry creates special opportunities to learn about the physical and chemical properties of substances by engaging the senses of the person conducting the experiment. In an ideal world, students could personally perform all the chemical experiments included in the curriculum as part of their chemistry education. However, this is not possible due to a number of restrictions [Wellington, 2007], including time and costs associated with the performance of the experiments as well as safety concerns. A solution to this situation is offered by virtual laboratories which, to a certain extent, allow students to experiment without the above-mentioned constraints [Millar, 2004; Bilek, 2010]. The literature describes different types of virtual laboratories offering varying degrees of involvement in the performance of experimental activities by students [Zeynep, 2010]. Most of the work focused on the computer software using the keyboard or mouse as input interfaces (Chemistry labs, nd.). The emergence of Natural User Interfaces (NUI) has created new opportunities for operating the simulation software. The software is controlled by natural movements and gestures of the user, making the virtual experiments more natural and intuitive. This enables the development of software with which the user will be more practically involved [Svec & Anderson, 1995].

Technical aspects of the software's design

What is NUI

Natural User Interfaces (NUI) is a type of interface, which provides the ability to communicate with various devices in ways which are natural to human beings. The task of an NUI is to create an interaction between the human and the machine in such a way that the user is not aware of the existence of the interface. NUI can operate in many different ways, depending on the needs of the user. A commonly used natural user interface is the touch screen interface. It allows the user to move and manipulate objects by touching and dragging their fingers across the screen. In this case, the objects on the screen may respond to touch, as well as real objects. This feedback via a touch-screen interface makes navigation seem more natural than with the keyboard and mouse. Most smartphone or tablet users do not realize that their interaction with the content is mediated by the touch interface [Murphy, 2012].

An example of NUI which particularly interested us is gesture recognition systems. They track the user's movement, which is then translated by the interface into instructions understood by the computer. Some of these systems, including the Nintendo Wii (Controls for Wii, nd.) and the PlayStationMove (This is How I Move, nd.) use accelerometers and gyroscopes for tracking the angle, speed and acceleration of movement. A more intuitive kind of NUI is equipped with a camera and software that recognizes specific gestures and translates them into action. Microsoft Kinect (Kinect for Windows, nd.) or LEAP Motion (LEAP Motion, nd.) [Kosner, 2012] allow users to interact with the device through body movements, gestures and voice commands. In addition to these common interfaces, there exist others. They may be based on voice recognition, eye movements or brain wave analysis (Natural User Interface, nd.).

Technology used to create the software

In creating software that simulates the school chemistry laboratory we relied on existing technologies. We used the Kinect package for Windows SDK. This package offers a number of tools, models and features to help developers create and improve applications that respond to human gestures and voice. It also contains drives for connecting Kinect to a Windows PC (Skeletal Tracking, nd.). School chemistry laboratory software was written in the computer C#. Additionally, during the development phase we benefited from the language .NET package of the Windows Presentation Foundation (WPF) which enables the preparation of a graphical user interface. This package was also used to create an on-screen graphic display interface (Windows Presentation Fundation, nd.). We also used the universal language of XML tags designed to represent different data in a structured manner (XAML Overview, nd.). In our case, it was used to describe the laboratory equipment, the chemicals, the instructions for experiments and the interactions taking place.

The resulting program uses the Kinect for Windows sensor to detect and analyze the movements of the user. This sensor has greater technical capabilities, such as higher scanning resolution and the possibility of smaller distance between the user and the sensor, than the Kinect dedicated for XBOX (Kinect for Windows, nd.).

Description of the simulation software

The simulation software used in this research enables a complete simulation of the actions performed as part of an experiment in a school chemistry laboratory. This includes simulating grabbing laboratory equipment and dishes and their appropriate installation. It is also possible to simulate pouring solid and liquid solutions into laboratory dishes and other laboratory activities. The software accurately simulates the movements of poured liquids and the movements of liquids which occur during chemical reactions as well as the movements of solid particles being poured into a laboratory dish. The software makes it possible to simulate 40 chemistry experiments. which are on the junior high school and high school chemistry curricula in Poland, such as, the comparing the chemical reactivity of metals, the characterization of carbon dioxide, obtaining hydrochloric acid by dissolving hydrogen chloride in water, studying the impact of temperature on the solubility of gases in water and on the rate of chemical reactions, or testing hydroxide and the acidity of oxides. We used a correctness monitoring system, whereby actions which are incorrect or inconsistent with the safety principles of laboratory work are signaled to user and blocked. The purpose of this is to familiarize the user with the rules of proper and safe work in the laboratory. In order to conduct research on the effectiveness of the software, we created three different versions of it. In the first version of the software, the student performs various laboratory activities in accordance with instructions provided in real time through a voice-over. In the second version of the software, the voice-over has been replaced by a video depicting the conduct of the experiment. These videos used multimedia instructions for performing the virtual experiments prior to the simulation itself. In the third version, conventional written instructions for experiments are used. Both the video instruction and the conventional written instruction are available to the student, upon request, during the simulations of the experiments. In all three versions, the monitoring system indicates when the student makes a mistake in the laboratory work



Fig. 01. Screenshot from the computer programme show general view of the virtual laboratory.



Fig. 02. Screenshot show incorrect laboratory procedure.

Description of the research methodology

The research problem

We want to examine which version of the chemistry laboratory simulation software gives the best results in terms of preparing students for work in a real school laboratory. This will point to the most effective method of developing laboratory skills, as well as identifying the instructions which are the most appropriate for the majority of the students at each educational level. We were also interested in how working with the chemical laboratory simulator affects the efficiency, confidence and independence of students in a real school laboratory.

Description of student groups

In the Polish education system is a three-year junior high school. Four groups of junior high school students participated in the study. The students were in their second year of study in their respective schools, because more hours are dedicated to chemistry during that year than during either the first or the final year. Each groups of twenty five students were assigned to different versions of the software at random. Care was taken to ensure that the numbers of students in each group were the same and that they did not change during the study. Altogether, 100 students participated in the study. Average ages were 14 for junior high school students.

The symbols used to designate each group are listed in Tab. 01.

groups designation	didactic tool	Number of students [n]
GKL	first version of the software with voice-over	25
GKF	second version of the software with videos	25
GKT	third version of the software with written instructions	25
GTF	instructions and videos without virtual laboratory software	25

Tab. 01. Designations of the groups of students, depending on the didactic tool.

The testing procedure

At the beginning of the study each group of students received a didactic tool. One group of students in each school prepared for the performance of experiments in the school chemical laboratory using the first version of the simulation software. The second group of students in each school used the second version of the software, and the third group of students in each school used the third version. We created a fourth group of students in each school to compare the results of working with the Kinect interface simulation software to the results of preparation of chemical experiments without that interface. Therefore, the fourth group of students worked only with the written and video instructions, without access to the virtual laboratory.

At the beginning of the study, all groups of students solved a pre-test designed to determine their initial level of knowledge associated with the chemical experiments performed during the study. Then each group of students followed their usual weekly schedule of chemistry lessons working with the didactic tool assigned to them. After the completion of the planned experiments students solved a post-test. The multiple choice questions which made up this test were related to the experiments they performed. Three months following the completion of the post-test, students were given a distance test. The distance test contained the same multiple choice questions as the post-test but they were arranged in a different order. We also conducted a survey of the students' opinion about the method of preparation for laboratory classes they used, and of the software itself.

The pre-test, post-test and distance test results were analysed according to the taxonomy of educational objectives developed by B. Niemierka [1977] the main categories and sub-categories of which correspond to Bloom's [1956] taxonomy and revised Bloom's taxonomy [Anderson et all., 2001] This taxonomy differentiates between knowledge and skills. At the level of knowledge, the taxonomy recognises as sub-categories objectives related to retention of information (A) and understanding of information (B). At the level of skill which has a higher didactic value, the taxonomy differentiates between application of information in a standard situation (C) and its application to a new problem (D).

The test results were used to calculate the increase in knowledge and skill in each group of students and thus the educational effectiveness of each version of the chemistry laboratory simulation software. We also determined the durability of knowledge in each group of students [Jagodziński & Wolski, 2012]. The chi-square test was used to determine the statistical significance of the differences in results.

The test results

Below we present a summary table of the test results achieved by the junior high school and high school students respectively.

Tab. 02. Results achieved by the junior high school students in the pre-test, post test and distance test expressed as arithmetical mean, mode and variance.

Categories in the taxonomy of educational objectives																
_		A			В		С		D		G(generally)					
Group	name	Tpr	T _{po}	T _{di}	Tpr	Tpo	T _{di}	Tpr	T _{po}	T _{di}	Tpr	T _{po}	T _{di}	Tpr	T _{po}	T _{di}
GKL	arithmetical mean ^a	1,60	4,76	3,96	1,40	4,44	3,60	1,40	4,36	3,48	1,20	4,04	3,24	5,60	17,60	14,28
	modal ^b	2,00	5,00	4,00	1,00	5,00	4,00	1,00	4,00	4,00	1,00	4,00	3,00	5,00	18,00	14,00
	variance ^c	0,50	0,19	0,62	0,42	0,67	1,00	0,25	0,41	0,76	0,75	0,54	0,77	2,67	1,83	8,71
GKF	arithmetical mean	1,64	4,60	3,56	1,48	4,16	3,12	1,32	3,80	2,76	1,28	3,36	2,56	5,72	15,92	12,00
	modalna	2,00	5,00	4,00	1,00	4,00	3,00	1,00	4,00	3,00	1,00	3,00	3,00	6,00	16,00	12,00
	variance	0,41	0,33	0,76	1,01	0,31	0,86	0,29	0,75	0,77	0,29	0,66	0,76	1,54	2,66	4,00
	arithmetical mean	1,72	4,72	3,36	1,40	3,84	2,92	1,28	3,52	2,52	1,08	3,16	2,36	5,48	15,24	11,16
GKT	modal	2,00	5,00	3,00	1,00	4,00	3,00	1,00	4,00	2,00	1,00	3,00	2,00	5,00	15,00	11,00
	variance	0,38	0,29	1,16	0,33	0,89	0,74	0,21	0,51	1,01	0,08	0,47	0,91	1,09	2,94	4,47
GTF	arithmetical mean	1,64	4,44	3,08	1,40	3,64	2,60	1,28	3,56	2,32	1,12	3,00	2,04	5,44	14,64	10,04
	modal	2,00	5,00	3,00	1,00	3,00	3,00	1,00	3,00	2,00	1,00	3,00	2,00	5,00	15,00	10,00
	variance	0,41	0,51	0,83	0,42	0,91	0,75	0,46	0,92	0,73	0,36	1,17	0,71	1,92	3,07	2,79

Note: Tpr - pre-test (pretest), Tpo - post-test, Tdi - distance test

a the arithmetical mean of the numbers of points obtained by students in each test,

b the most frequently occurring result in the set,

c the measure of variability of the observed results.

The results of the junior high school pre-test (Tab. 02) indicate an even level of knowledge among the participating students. Most of them answered two out of five questions correctly within category A of the taxonomy of educational objectives. However, in the case of taxonomic categories B, C and D, the majority of the students only answered one out five questions correctly in each category.

The results of the post-test given in the junior high school (Tab. 02) indicate that students in the GKL group (instructions delivered in real time by a voice-over) achieved better results across all the taxonomic categories compared to the other groups of students. The observed differences increased with the increase in the values of taxonomic categories, with the largest differences observed with respect to category B, the majority of the students from the GKL group answered all questions correctly, while most students in the GTF group answered correctly only three of the questions correctly. In category C, the same number of correct answers, that is four, was recorded for the GKL, GKF and GKT groups of students. The GTF group obtained the comparatively worst results, because the majority of the students in this group gave the correct answers to only three out of five questions. In the case of category D, which is the category with the highest taxonomic value, the best results were obtained by students from the GKL group the majority of whom answered correctly four out of five questions. Most students in the other groups answered only three questions correctly.

The results of the distance test among the junior high school students indicate that students from groups GKL and GKF answered correctly four out of five questions in the taxonomic category A, while the results of the students from groups GKT and GTF were lower with only

three questions answered correctly. Within taxonomic category B, the majority of students from group GKL answered correctly four out of five questions, while the other groups of students achieved similar results, the majority of them answering three questions correctly. In taxonomic category C, the best results were achieved by group GKL, with the majority of the students from this group answering four questions correctly. In this category, the majority of group GKF students answered three questions correctly, and the majority of students from groups GKT and GTF gave the correct answer to only two questions. In taxonomic category D, which concerns the problem solving skills, the majority of students from groups GKL and GKF achieved similar results by providing correct answers to three questions, whereas the students from groups GKT and GTF gave correct answers to two questions on average.

Tab. 03. Summary of the results of the increase in knowledge, the learning effectiveness of the didactic tools of sustainability of knowledge, achieved by each group of junior high school students working with the didactic tools which were the subject of the study.

Categories in the taxonomy of educational objectives									
	Α	В	С	D	G(generally)				
Group symbol	Growth of s	Growth of students knowledge [%]							
GKL	198	217	211	237	214				
GKF	180	181	188	163	178				
GKT	174	174	175	193	178				
GTF	171	160	178	168	169				
	Educational	Educational effectiveness of each pair [%]							
GKL – GKF	7*	13*	19	37	18				
GKL – GKT	5*	25	32	37	23				
GKL – GTF	13*	36	30	51	30				
	Sustainabili	Sustainability of students knowledge [%]							
GKL	83	81	80	80	81				
GKF	77	75	73	76	75				
GKT	71	76	72	75	73				
GTF	69	71	65	68	69				

Note: The sign (*) indicates statistically insignificant results, determined from the chi-square test.

After solving the post-test, all groups of students answered a survey. Below we present questions included in survey:

1. Working in a virtual laboratory using the Kinect interface is pleasant and interesting: a) yes, b) only partly, c) not at all, d) I have no opinion

2. Do you consider using the virtual laboratory at home an appropriate method for preparing to work in the school chemistry laboratory: a) yes, b) only partly, c) not at all, d) I have no opinion

3. Are the instructions provided with the simulation software useful in performing virtual experiments: a) yes in 100% of the cases, b) yes in about 75% of the cases, c) half the time, d) only in 25% of the cases

4. To what extent does the virtual laboratory equipment correctly reflect the actual chemical laboratory: a) 100%, b) 75% c) 50%, d) only 25%

5. To what extent do laboratory activities performed during virtual experiments reflect the real operations carried out in a school chemistry laboratory: a) 100%, b) 75%, c) 50%, d) only 25%

6. Has working with a virtual laboratory helped you to work in a safer and more flexible manner in the school chemistry laboratory: a) yes, b) only partly, c) I have no opinion, d) no

7. Has performing virtual experiments increased the efficiency of your work in the school chemistry laboratory: a) yes by about 25%, b) yes, by about 50%, c) yes, by about 75%, d) the efficiency of my work has not increased

8. What caught your attention the most during the work in the school chemistry laboratory: a) the substantive part of the task, b) the manual part of the task, c) the correct installation of equipment, d) the proper performance of the experimental procedure

9. To what extent has working with a virtual laboratory increased your interest in chemistry: a) by 25% b) by 50% c) by 75%, d) it did not increase my interest

10. To what extent did your emotional engagement in the study of chemistry increase following the use of a virtual laboratory with the Kinect sensor: a) by 25% b) by 50% c) by 75% d) the virtual laboratory did not arouse any emotions in me

The survey results are presented in Tab. 04.

Tab. 04. The combined results of the survey (from both junior high and high school).

		Anserws							
Question		а	b	c	d				
		[%]							
1		68	25	2	5				
2		76	19	3	2				
	GKL	93	5	1	1				
3	GKF	84	11	3	2				
	GKT	71	17	9	3				
4		97	2	1	0				
5		47	38	12	3				
6		89	11	0	0				
7		58	27	13	2				
8		43	36	13	8				
9		39	36	18	7				
10		46	27	17	13				

* NOTE: The answers to question 3 were divided into three parts according to the type of instructions used

Discussion

The results of the pre-test conducted in the junior high school indicate that the participating students had an evenly low level of knowledge of the topics within chemistry covered in the study. Even levels of knowledge within the groups indicates that the groups were put together correctly and could be used in the study.

The analysis of the results of the post-test administered to the high school students shows that group GKL achieved the best results. Students in this group, when performing virtual experiments, worked according to instructions delivered in real time by a voice-over. It can be concluded that this version of the virtual laboratory software suited the most students, because today's media, to which students are accustomed, is dominated by a combination of video and audio content. The results of group GKF that performed virtual experiments according to instructions in the form of videos with commentaries, are about 11% worse than the results of students in group GKL. Removing the voice-over which offers the instructions for laboratory activities piecemeal as they are performed by the student at their own pace (pieces of information) and replacing it with multimedia content in the form of video in which these activities are given in one chunk and at a pre-determined rate (accumulation of information) reduced the effectiveness of instruction by 18% (Table 3). The post-test results of the students in group GKT are almost identical to those achieved by group GKF. This shows that the conversion of film instruction to text displayed on the screen does not alter the effectiveness of instruction. This is due to the fact that the text instructions, as well as the film instructions, provide the most important information in a concise, cumulative way. Students of group GTF who worked with text and film instructions but without the virtual laboratory achieved the worst results. Taking away from the students the ability to simulate laboratory activities resulted in less engagement in the experiments, which could result in worse results. Considering the results obtained in terms of the educational objectives, it is apparent that group GKL achieved relatively high scores across all four categories of the taxonomy of educational objectives. The other groups of students, that is GKF, GKT and GTF, achieved similar results in the taxonomic category A. The choice of didactic tools had no significant effect on the degree of differentiation knowledge retention by high school students. This is shown by the results of the educational effectiveness of the didactic tools in taxonomic category A, where the differences are not statistically significant (Table 3). In terms of understanding the message, however, as per taxonomic category B, we observed differences in the educational effectiveness for students only between groups GKL-GKT, on the one hand and GKL-GTF, on the other hand. Interrupting the experiment to read the instructions has as negative an impact on the understanding of the message as the lack of simulation altogether. For students in group GKF, the difference is statistically insignificant. In the case of taxonomic categories C and D, which relate to problemsolving skills, the best results were achieved by group GKL compared with all the other groups of students. This gives the didactic tool used by this group a big advantage because these two taxonomic categories are associated with skills with the highest teaching value. Here the positive impact of voice-over acting as a virtual instructor can be seen most clearly.

With respect to the sustainability of the junior high school students' knowledge, it is the highest among the student in group GKL. Also from this perspective, the use of a virtual laboratory where students were receive voice-over instructions in real time, turned out to be the best combination of the didactic tools.

Based on the survey results, it can be concluded that the virtual chemistry laboratory using the Kinect interface was valued by the students, especially because it allowed them to independently carry out chemical experiments under almost any conditions. There is a co-relation between the results of the survey and the results obtained by students in the post-test and the distance test. Most of the students said that working with the software was interesting and appropriate as a way to prepare for chemistry lessons. They particularly underlined the advantages of the opportunity to work with the software at home. Out of the various methods of communicating instructions for the experiments, the students expressed preference for commands given by a voice-over accompanying the performance of the simulation. They also stated that the graphic elements depicted in the virtual laboratory accurately reflected an actual laboratory. Students also confirmed that the laboratory activities performed as part of the virtual experiments largely resembled the actual operations. Most of the students expressed the view that, after training in a virtual laboratory, they were able to work more safely and more independently in a real school chemical laboratory and that their work was more efficient. After practicing with the virtual laboratory, students were able to focus more on the substantive aspect of the job rather than on the technical side when they were in the real laboratory. The use of a virtual laboratory increased students' interest in chemistry and their emotional involvement in the study of the subject.

Summary

The research presented above leads us to the conclusion that the use of a natural user interface, such as Kinect, with appropriate software leads to good results in chemistry teaching. This interface significantly increased the realism of the simulated experiments, which led to the students enjoying their work in the virtual laboratory. When interviewed, the students underlined the ability to perform the manual tasks almost as if they worked in a real laboratory. They also noted the possibility of multiple repetition of the same experiment without worrying about the cost of the reagents. They expressed surprise when the program informed them of the dangers associated with the experiments, because in their view nothing could happen to them. However, it was our intention to introduce students, already at this stage, to the laboratory safety rules. Most of the available programs that allow users to simulate experiments and chemical processes are controlled through a computer mouse and a keyboard. Our program uses neither; it is controlled by hand gestures. Whilst performing the virtual experiments, students become emotionally involved, much as they do when playing computer games, which elicit high emotional involvement from users [Khan, 2007]. The advantage of our program is the ability to use it in a variety of settings, including at home, to prepare for chemistry laboratory classes.

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Piotr Jagodziński, Robert Wolski

Department of Chemical Education, Faculty of Chemistry, Adam Mickiewicz University, Poznań, PL

piotrjot@amu.edu.pl, wola@amu.edu.pl

CHEMICAL EXPERIMENT IN EDUCATIONAL FILM IN 2D AND 3D - THE DEVELOPMENT OF IMAGE RECORDING TECHNIQUES AND THEIR IMPACT ON CHEMICAL EDUCATION

Piotr Jagodziński

From Edison to educational videos in Chemistry

The rapid development of various techniques for recording and image presentation resulted in the invention of the light bulb by Thomas Edison and patenting the invention which was the cinematographer by Lumière brothers in 1895. They constructed a device and organized in Paris the first screening of the film its title Employees Leaving the Factory that watched 35 people. They have developed the principle of photoreceptors that is the creation of panoramic photography. In the studios in London in 1907 year Lumière brothers began producing panels for color photography by autochrome method, and in 1935 drew up a two-tone method of presentation of three-dimensional movies popularly called anaglyph images [http://pl.wikipedia. org/wiki/Bracia Lumi%C3%A8re, http://www.youtube.com/watch?gl=PL&hl=pl&v=YX D56XL4R80]. All these inventions gave rise to the development of documentary and feature films and, eventually, to the formation of films with educational value. In 1924, at the Second Conference Colloid Symposium at Northwestern University and at the Fall Meeting of the American Chemical Society w Ithaca was presented one of the first educational films showing Brownian motion observed during the coagulation of the colloidal solution of gelatin [Kraemer, 1924, p.199]. A year later appeared sets of educational videos produced by the Pittsburgh Experiment Station [Miller, 1925, p.1068]. Produced films were then executed in black and white technology. Soon, however, they gave way to films realized in color technology. Their advantage was ability to capture the image in natural colors, they more accurately capture the registered reality [Arnsfiger, 1926, p.200]. Published films were stripped of their sound. It was only in 1929 at a meeting of the Division of Chemical Education, which was held in Columbus were presented the first accompanied by sound educational films in chemistry [Grafflin, 1931, p.972], and the following years brought their further development [Richmond, 1931, p.848, Read, 1937, p.500]. During World War II the development of cinematography, including the educational films has been significantly slowed. However, were published, though in smaller copies educational films about the qualities of training for the army. As an example can be used training videos realized for the needs of the U.S. Army showing manual use of various types of equipment designed for various military formations [Chemical Warfare Service, 1942, p.137]. At the end of the war in 1945 there was a revival in world cinema. Began to appear new films of educational value. Example can be movies showing animations instructing execution of the basic techniques of working in a chemistry lab. Was performed research into the usefulness of these films during the course of quantitative analytical chemistry and general chemistry at Ohio State University. At the same university, created and also studied a short film sequences involving issues concerning general chemistry, such as the concept of atomistic Dalton, Modern nuclear chemistry, the atomic theory of Bohr [Wirth, 1945, p.501, Garret, 1948, p.544]. More and more perfect photographic equipment, footage and cinematic has prompted the authors to carry more and better films in which it was possible to use various technical techniques called film tricks.



Fig. 1. Movie studio in the '50s Harvard University, Cambridge, Massachusetts [Fieser, 1957, p.3]



Fig. 2. Scene from application of the Nernst Partition Law [Fieser, 1957, p.3]

The next decade was associated with the development of television, and hence the adaptation of educational videos on its needs. In contrast to the emission of footage on a projector, where the number of audience was small and limited, television allowed access to educational materials to incomparably wider audience. Thanks to emission of footage via television the cost of production of educational materials could be significantly reduced [Slabaugh, 1959, p.590]. In the next 60 years, in parallel with the development of television there was a miniaturization of modern film equipment. Convenient to use and relatively easy to use were projectors, in which as a image carrier was used film tape with a width of 8 mm. The German company Zeiss patented and produced compact projector with a magazine for this type of tape, which allowed easy and rapid selection of the theme of the film, and the function of remote control via wired remote control that enable scrolling, stop, focus, and choosing part of the film which has so far been impossible. It was also possible to play videos in slow or fast pace and the use of freeze-frame shot. Under these conditions, the film tape did not undergo destruction due to the high temperature of the light source, because between the film tape and the light source was used a glass filter absorbing thermal radiation [Bernard, 1968 and, p.136].





Fig. 3. Compact and inexpensive Kodak projector on film tape with a width of 8mm [Bernard, 1968 and, p.136]

Fig. 4. Zeiss projector having an integrated screen and a steering [Bernard, 1968 and, p.136]

In the 60s of the twentieth century there has been even more rapid development of television. Both television programs and film programs, especially educational programs were created on the basis of detailed scenarios developed by the universities. Valuable teaching aid for teachers have been implemented in those times television programs, showing entire teaching units. This was particularly important for the young adepts of the teaching profession. Undertaken also attempts to use television in the teaching of large groups of students. This was done in such a way that the theoretical classes, including lectures were presented on TV monitors placed in large lecture halls. Were also tested the live image transmission. This involved on sending a TV signal of events taking place under the watchful eye of a television camera in one room to a few more rooms in which were pupils or students. At that time, the sensation began to make the newly produced first video recorders allowing permanent image recording on magnetic tape. The introduction of video recorders for sale greatly facilitated the production of educational programs and not only professional but also created by teachers or students for internal use of educational activities. Example are a laboratory instructions prepared by the teachers and students presented before laboratory classes to students [Bernard, 1968 b, p.617, Bernard, 1968 c, p.681, Bernard, 1968 d, p.745].







Fig. 6. Installation diagram of school cable [Bernard, 1968 d, p.745]

Computers in the creation of educational videos - new opportunities

Great freedom in creating programs and educational films posed entering for the production devices called computers. In 1969 appeared first publication describing the educational use of computers to create animations presenting oscillator vibrating of atoms in the molecules of selected chemical compounds. Implemented algorithms allow to create animations that were presented on the monitor. For calculations and creating animation was used IBM 360-50 computer with the IBM 2250 CRT Scope monitor. Then the first attempts were made to create videos that contain animations generated by a computer. This was a significant step forward, especially in the visualization of the microworld. This kind of animations allow to better understanding of certain physical and chemical phenomena, which has so far been very difficult because of the technical limitations of the available hardware [Walton, 1969, p.335]. The technical development of film equipment caused greater its availability due to lower production costs and purchase. This allowed easy access for students and pupils to that equipment and, consequently, making a quick and simple films created by them for the teaching purposes. These films often do not have a professional quality but served well as a instructions for students or pupils before the beginning of laboratory classes. How much become cheaper the cost of creating such materials in the 70s, you can see on the example of similar production cost analysis of the 60s. Then producing one minute educational film cost from \$ 600 to \$ 1,000. Ten years later, the cost of one minute educational film decreased about 100 times and amounted approximately \$ 5 [McGrew 1970 p.763]. At this time also was developed and popularized innovative teaching method that uses video recordings in the educational process. For example were recorded students preparing for the teaching profession. By this method called microteaching were trained to perfection individual
teaching activities. Among other things educated the ability to use of certain teaching methods. This was done by video recording and critical analysis of students speeches and the repetition of these steps until their correct master [Mellon, 1971, p.675, Bush, 1964, p.78, Allen, 1969 p.245].



Fig. 7. Mikroteaching in practice [Mellon, 1971, p.675]

In the next years, the development of educational films proceeded with an emphasis on the development of a methodology for creating and improving their substance quality. Each teacher could further create educational films for the use of it in the conducting by him classes. Preparation of short films or film sequences, however, required a certain time dedication and implementer skills. Therefore, self-production of films with specific educational values was possible after fulfilling the following conditions:

- realization of the film should involve the smallest amount of a teacher time - the executor,

- should provide a quick preview of the realized fragment of the material to evaluate and make the necessary changes,

- realized movies should have a linear structure due to the film implementation in one piece without the need for assembly

- before proceeding to movie production technical needs for its implementation under the prevailing conditions should be an assessment, so its final version could be widely applied using various types of equipment [videos, projectors, etc.]

- during film making should be planned stage of internal substantive and methodical assessment of recorded material by teachers and students

- during film making should be reduced to a minimum participation of professionals, which significantly will reduce the cost of production

- should be properly planned the media type of video and audio so that it can easily convert between storage media: film reel, video cassettes, Electronic Video Recording [EVR] or electronic recording system based on light-sensitive film tape [http://en.wikipedia.org/wiki/Electronic_Video_Recording, Wetmore, 1971, p.617].

In the 70s of the last century we can also observe significant development of technical devices designed to record video and audio data and for its playback. Teachers - executors of movies, mostly for internal use, had already access to equipment such as rearscreen projectors, the image and sound recorders for recording color image on magnetic tape [Sony U-Matic, VHS Panasonic] [Bernard, 1973 p.66, Bernard, 1974, p.624]. During these years, they can also use cheap ready sets to organization of small, portable video studio, which included: laboratory table, studio lamps, movie camera [Burnett, 1977, p.243]. A unique innovation in those years were the first attempts to create computer animation and then use them in educational films. This has opened new opportunities to translate complex technical chemical issues, such as: the mechanisms

of chemical reactions, crystal structure, spatial structure of chemical compounds, interactions between molecules and atoms, etc. [Raff, 1974, p.712, Brooks, 1978, p.19]. Popularity and access to technical resources enabling registration of image and sound and also better educated workforce of educators resulted in preparing by their teams courses registered on video tape and covering material throughout the semester [Jegl, 1978, p.227]. The 80s and the first half of the 90th brought no technical novelties. During this time, popularized and strengthened VHS system using magnetic tape as the main carrier of information. However, the quality of picture and sound recorded in this system was slightly worse than in later created SVHS registration system - giving the image a much better resolution and color quality. This system was willingly used by executors of educational programs in chemistry recording images in the sphere of the microworld, where high quality of reflecting fine detail is a key factor.

Era of digital technology

In the late 90s there was a new era in filmmaking with particular emphasis on educational films, due to the development of new learning technologies with using computers and the popularity of digital techniques in film and photography. Digital techniques required new image carriers that allowed at the same time rapid registration of images, the possibility of immediate viewing, simple way to retouch the image and influence on its final version and allowed the non-linear montage of footage which in the case of analog techniques was difficult, and in some cases impossible. The first widely used a digital carrier was CD. Data were recorded in MPEG-1 introduced in 1993 by Philips and Sony corporations. This was the first step towards the creation of computer multimedia programs containing film sequences [Ben-Zvi, 1992, p.304, Rheingold, 1994, p.580]. Until now simple creation of programs containing on-screen at the same time various multimedia elements such as static images, animation, text, video sequences were difficult or impossible [Whitnell, 1994, p.304]. CD gave the ability to easily playback located on its information using a computer or VCD [Video Compact Disc] connected with the TV. Development of VCD technology was to developed in 2005 a DVD [http://en.wikipedia. org/wiki/DVD]. It differed from the CD, by the volume of information that can be stored on a DVD. Changing the compression format from MPEG-1 that was use to the information stored on VideoCD discs to MPEG-2 for DVD discs resulted in a significant improvement in the quality of the playback picture. Development of technologies of the preparation of pure gallium nitride crystals by Polish scientist dr. Sylwester Porowski enabled the production of the blue laser used to read and write information on Blu-ray. This allowed for introduction of a new compression format designated as MPEG-4. This type of compression is also used in modern digital television [http://blu-raydisc.com/en/AboutBlu-ray/WhatisBlu-rayDisc/HistoryofBlu-rayDisc.aspx].

Interactive digital TV programs

Digital television allows for the implementation of educational programs in which novelty is the interactivity between the viewer and the content and the events happening on the screen. The HbbTV [Hybrid Broadcast Broadband TV] technique allows you to combine the advantages of standard emissions of digital TV with multimedia content delivered via broadband Internet. It is a hybrid interactive television, in which it is possible to prepare a television interactive applications. The great advantage of the interactive television is that these applications deliver additional content during the transmission of a live TV program [http://en.wikipedia.org/wiki/ HbbTV]. Thanks to modern technology that uses the Internet network it is possible to transfer files with record of media, which play takes place in the same moment in which it is sent. In practice, streaming multimedia files allows them to play without downloading it by the computer of the recipient. In this case, the media files are not stored on disk. This technology successfully is starting to be used in distance education, because users of remote training courses can use, for example, from library of films, broadcasts, interviews, etc. placed on the servers, and played on electronic personal devices such as laptops, PCs, smartphones, tablets, without restrictions of time and place [http://en.wikipedia.org/wiki/Streaming media]. In the mid-90s of the last century was developed a new technology involving the digital video recording and sound. The first digital cameras were recording in standard definition image called SD [standard definition] PAL or NTSC [http://en.wikipedia.org/wiki/Standard-definition_television]. In 2003 was produced a camera for general use with the ability to record images with a higher resolution marked as High-Definition [HD], and in subsequent years, started production of the world's first cameras that images were even in higher resolution marked as Full HD. New technologies, image recording and sound continues to develop which can be confirmed by the appearance in 2011 of the first 3D camera, that is recording an image that retains its depth during playback. The technique of digital recording gives you easier access to editing multimedia files. Registered material can be edited using the appropriate software. Then it is possible to transform the material into different formats and save it in different files. This allows you to copy a movie on the VCD, DVD, Blu-ray or any other medium, even on VHS [Jeffrey, 2004, p.29].

Examples of the use of new digital technologies in the creation of educational videos and teaching aids

In the Department of Chemistry Teaching, Adam Mickiewicz University for many years as one of the themes of research, educational videos were implemented and were carried out researches into their usefulness in chemical education using technology described above. Until the mid-90s in education Polish films were used as a separate means of communication, which has not yet been coupled with other teaching measures such as multimedia programs. This was due to technological limitations, that is lack of appropriate hardware and software. Also in these years was observed just the beginning of the implementation of digital techniques and they were not even well known, and much less used in accordance with the principles of teaching in the educational process. To meet the needs of schools in the years 1996 - 1998 were prepared sets of educational films corresponding to the core curriculum of chemistry in the primary school and high school [BUREWICZ, 1997]. Movies was realized then with the analog method consisting of image recording using an analog camera on S-VHS tape. Image captured in this system was in high quality. Tapes with recorded in this way sequences were therefore good starting material called matrix to copy them on VHS tapes to disseminate recorded programs - educational films. The material on movies, and especially the course of chemical experiments and animations worked in chemical education to the extent that the films have been used by teachers as a valuable source of information and useful means of teaching. Therefore, when the DVD became popular in the 2004 material was converted to digital form, allowing to watch movies using DVD [BUREWICZ, 2004]. Material on discs concerned, inter alia, methods for the preparation of hydroxides by the action of water on metal oxides, the chemical reaction of acids with alkalis, preparing and testing the properties of the simple aliphatic hydrocarbons, testing and construction properties of unsaturated hydrocarbon molecules, etc.. Programs in those years were the precursor programs, and therefore as a valuable means of teaching have been included in the register of the Ministry of Education and Sports as recommended to study chemistry at the secondary school and high school. As part of a research project funded by the Committee for Scientific Research in the years 1998 - 2001 were prepared multimedia academic textbook Didactics of protection of the environment bringing up issues related to the organization of the learning process, learning goals, principles of teaching, teaching methods, teaching resources and their use in teaching, workshop for environment protection, retention and supervision of school achievements, preparation of the teacher for the lesson, teaching selected topics of environment protection, rules of curriculum creation. In the handbook were placed photos and film sequences. It was realized only in digital technology, which at the time was a complete novelty. Thanks to that it was possible to keep track of both the course of chemical experiments performed in the laboratory, as well as the course of natural phenomena occurring in the environment. Thanks to digital technology it was also easier to take pictures and macro photography, so that you could look inside the tube and watch chemical reactions taking place in it. At making films for the purpose of this handbook were used a nonlinear montage of film sequences. It allowed to add subtitles, graphics, lecturer commentary and background music in easier way. Digital techniques and adequate tools in the form of computer

software Adobe Premiere allow to use new products, which it was then putting in one image the dynamic portions of the second dynamic image. The used equipment allowed to use digital technology timelapse difficult to perform during video recording by analog method on film tape. Thanks to this the phenomena occurring very quickly was able to watch in slow pace making potential observations, such as observations of lightning in the tube during the chemical reaction of oxidation of ethyl alcohol in the form of atomic oxygen. It gave a more scientific character to films, and presented images more strongly attracted attention of the user - the student or the teacher, leading to better understanding and assimilation of the presented content and phenomena [Burewicz, 2002 and, p.1055]. Development of the use of digital techniques in film education was the preparation of a multimedia educational program "Intensification of agricultural production and the associated risks. Organic farming, "Program includes selected films presenting aspects in the field of chemistry and nature. They can serve introducing primarily the function for students to new problems. They have educational advantages and are well suited for use on the high school level, especially in classes of biological and agricultural professional profile. These films can also be used at the level of higher education because methodical housing of films creates such opportunities [Burewicz, 2004 b, p.367, Burewicz, 2003, p.89]. Here is a frame from the selected movie:



Fig. 8. Frame from the film titled "Manufacturing of acid products by plant roots"

In the experiments presented in the films emphasis is placed on analytical methods for the determination of soil chemical elements necessary for plant life.

There was research on the effectiveness of educational films included in this program. The research involved comparing the results of students work. During work, the experimental group of students performed in class chemical experiments using[as a help] manual experiments in the form of video sequences. The control group consisted of students using the content and instructions for experience in conventional descriptive form [Burewicz, 2004 c].

The results show that students working with films needed about 23% less time to complete the experiment than control group. Increase of students knowledge in control group was 21.6%, and the of students in experimental group was 35.1%. Therefore the didactic effectiveness of tested educational program is 13.5%. From studies on stability of students knowledge designated from knowledge loss, in the experimental group was higher it was by 15.5% compared to the control group of students. The calculations confirm that the differences in the educational effectiveness are statistically significant.

The program was enriched by methodological guide, which is an important part of the package. Methodological guide shows you the possibility of using different teaching treatments during film emission while giving you the freedom of choice [Burewicz, 2006 a].

The use of digital techniques has saved the time needed to prepare often difficult to produce films. By using non-linear editing was possible fragmented implementation of several video sequences of the various experiments. Further folding of the material in this case does not cause problems since finding corresponding sequences necessary for the assembly of a certain movie in a whole does not cause technical problems.

Films presenting selected techniques of laboratory work are an interesting example of multimedia instruction. Here is an example of the frame from the film.



Fig. 9. Heat treatment of glass

With the techniques of digital recording and image processing, it is possible to combine simple computer animation and film sequences gaining synergy effect that is multiplied educational benefits through the skillful combination of these components. That technical procedure was used in films presenting selected techniques of laboratory work. Prepared in this way films are useful for those people who begin laboratory work. They are suitable also in training new teachers beginning to work in the chemical laboratory. In addition to all the laboratory techniques were prepared films of course of chemical experiments using specific techniques of laboratory work [Burewicz, 2006 b, p.196, Jagodziński, 2004, p.317]. Also was realized a package of interactive movies in chemistry for high schools. Movies created in digital technology and branched structure combined with the appropriate multimedia application allows user to interact in the course of the film. With this program you can select different variants of answers suffering the consequences of their choice in the form of an appropriate evaluation. In the case of the films discussed above. by implementing digital technology it is possible to control playback using a computer program. In this situation, played movie can be stopped at any point, defined by the program or user, and then it is possible to jump immediately to a specific other place consciously chosen by the learner. In the same way you can go back to the place where you made the decision. These technical procedures were used during preparation of films concerning problematic laboratory tasks. These films show chemical experiments, and the structure of films that is designed so they largely play a verification function, especially in the teaching using problematic method. Prepared films were carried out in three variants. The first option concerned chemistry experiments with the properly conducted experience. These films are used in the teaching of chemistry in the progressive part of the lesson and are directed to those who are learning chemistry. The second and third films variants shows the course of the experiment, in which were used inappropriate chemical reactants or improper course of experiment. These types of experiments along with the first version are designed for students checking their knowledge, for example after the completion of a certain partof material or preparing for a test or exam [Burewicz, 2007 a, p.133].

Obtaining ethyne from calcium carbide



Fig. 10. The proper operation of a chemical reaction product - flammable ethyne



Fig. 11. Checking the students knowledge Inappropriate variant of a chemical reaction for obtaining ethyne

Research were conducted on the effectiveness of these educational videos among high school students. Increase of the knowledge and educational effectiveness of studied educational films was determined for four taxonomic categories goals of education in the field of storing knowledge, understanding new information, application of knowledge in typical situations and the use of knowledge in new problem situations. From the students test results was found that within the control group knowledge increase amounted to 28% , in the context of memorizing 27% in the context of understanding, 25% in application of knowledge in a typical situation, and 36% in the application of knowledge in problem situations and within experimental groups of students increase in knowledge amounted to 56%, 49%, 65% and 73%. Therefore the effectiveness of educational films studied in terms of different categories of taxonomic training purposes amounted to A - 28% B - 22% C - 40% D - 37%. The results indicate a higher achievement of students from the experimental group and shows the fact that the studied didactic measure is beneficial for learning process of the chemistry especially in the use of knowledge in typical situations and problem solving tasks [Burewicz, 2007 b, p.138, Burewicz 2007 c, p.206].

The combination of Internet technology with films realized in a digital system has created new opportunities in education. Learners themselves can select appropriate content according to their needs. With stream data transfer in the form of a file containing film sequences learners can familiarize themselves with the material of choice in any place, time and regardless of the type of hardware. These technologies authors used when preparing the script for students in the web version. It is a set of instructions for chemical experiments presented in the form of short video sequences. Also were placed collections of reagents pictures, laboratory equipment and key moments in the course of the experiment. Multimedia guide was placed online at www. eksperymentychemiczne.pl. [Jagodziński, 2011, p.335].

Research were conducted on the effectiveness of multimedia online education script in groups of students of the Faculty of Chemistry realizing an optional subject Chemistry Experiment and among groups of postgraduate teachers improving their professional skills.

Work of students and teachers were divided into two phases in line with the modern methods of education which is blended learning. In the case of participants in the control group the first step was to prepare for classes at home using accordingly a conventional script. In contrast, participants in the experimental groups were preparing for the classes using the Internet script. Preparing for classes included obtaining an understanding: the detailed instructions of experiments, performed on a given day, the course of the experiment, with a description and explanation of the chemical reaction, the equations of chemical reactions, as well as answering on questions in the control block.

Determined how Internet media script used in blended learning method affects the effectiveness of educational training with the use of chemical experiment respectively for students and teachers [Jagodzinski, 2012 and, p.9].

Tab. 1: Educational effectiveness for different taxonomic categories of the chemical education purposes and for all categories together

Taxonomic categories	Educational effectiveness				
	Students	Teachers			
A-Activities related to remembering the knowledge	47,1%	6,1%			
B - Activities related to understanding of knowledge	22,7%	12,2%			
C - Activities related with the use of knowledge in a typical situation	35,1%	18,2%			
D - Activities related with the use of knowledge in problematic situation	60,1%	39,6%			
All together ABCD	36,7%	28,5%			

Educational effectiveness of multimedia Internet script with chemical experiments in blended learning method for different taxonomic categories A, B, C, D presented in Table 1 Educational effectiveness appointed jointly for all taxonomic categories of learning objectives for students is about 8.2% higher than in the case of teachers.

Students and teachers from the experimental group performed more than adequately experiments, than students and teachers from control group. Using Internet media script with any number of repetitions of the experiment make it easier to carry put them in the chemical laboratory, which effectively reduces the time required to perform one experiment. Although in a conventional script were included pictures from the course of experiments a control groups of students and teachers achieve worse results within the time required to perform one experiment.

Conducted researches confirmed the effectiveness of the educational use of Internet media script in teaching the subject of Chemical Experiment conducted by students of the Faculty of Chemistry, Adam Mickiewicz University and the Teaching of Chemistry Course conducted by postgraduate teachers with the use of training methods via the Internet. The use of this script and the described method allowed to increase the efficiency of education in the field of chemical experiment both for students preparing to become chemistry and science teachers and also teachers improve their professional skills.

Due to continuous development of electronics is possible miniaturization of many devices that become the equipment of personal use. These devices provide new opportunities to apply them in daily life and education. These include mobile and compact devices, such as smartphones, tablets, ultrabooks, etc.. Capacity and performance of these devices is now so large that you can store in them and play through them the footage that lasts many hours. Digital technology enables the compression of video footage, corresponding to the parameters of the device. Thanks to this to familiarize with film instructions learner in the classroom can easily take advantage of multimedia resources. If it is possible to connect devices with the Internet an additional use of online resources is available [Kukulska-Hulme, 2005, p.8].



Fig. 12. Use of palmtop as a multimedia	Fig. 13. Graphic presentation of mobile devices
collection of chemistry experiments. Determining	function [Kukulska-Hulme, 2005, p.8]
the properties of the substance	

Multifunctionality of these electronic devices and their mobility makes that they become modern didactic aids supporting teaching, among other things, natural sciences, especially in laboratory work.

Using these advantages was prepared package of educational films illustrating the course of some chemical experiments and presenting multimedia instructions of these experiments. These multimedia instructions of chemical experiments were used in realization of Chemical Experiment subject, during laboratory exercises by students of the Faculty of Chemistry, Adam Mickiewicz University, as well as by teachers from didactic chemistry on postgraduate studies at the Faculty of Chemistry, Chemical UAM [Burewicz, 2008].

Preparation of this package of films intended for smartphone use consisted of several stages. The first step was to select a set of experiments in order to prepare a set of multimedia instructions for chemistry experiments. The second stage involved the implementation of these multimedia instructions in a film studio. In the third stage was to made digital processing video sequences in the plane of the image and sound. The fourth step consisted of appropriate video compression, so that it was possible to play them using smartphone. For the video compression PocketDivXEncoder program was used, with which the entire set of films were prepared. Ready package of films was copied to the SD card and the card was placed in palmtop. Also was installed media player The Core Pocket Media Player [TCPMP] for viewing films, which were prepared with the use of Divx compression [http://www.pocketdivxencoder.net/EN_index.htm].

During the conducting of educational research, students and teachers preparing for classes used the same set of multimedia instructions for chemistry experiments located in palmtop. These experiments were performed by them during laboratory exercises in chemical laboratory. Learners could use the multimedia instructions for experience listed on smartphone at any time, for example, when solving a specific problem or performing certain laboratory activities.

Particularly important is the chemical education assisted by educational film for learners with physical disabilities. Were prepared two packages of educational films presenting the course of chemistry experiments for secondary school and high school deaf and mute and hard of hearing youth. Preparing a special version of films required a special approach to teaching chemistry and presentation of chemistry experiments. In this case important was the pace of provided information, timbre of voiceover communicating important information about the experiment or the iconic characters in the film. Image contains additional graphic signs to facilitate the perception of image layers. Exceptional importance in the educational films depicting the course of chemistry experiments, has a translation of comment for deaf students in sign language. Sign 80

language is quite poor in the characters signs. Therefore particularly difficult is the translation of chemical texts and comments. For the purposes of films made by the authors, has been specially created additional set of sign characters, especially for the chemical determinations.

Below are presented frames from films designed specifically for learning chemistry in high school and secondary school for deaf and mute and hard of hearing youth.



Fig. 14. Receiving methane on a laboratory	Fig. 15. The role of sign language in the
scale and method of collecting methane	description of molecular modeling of unsaturated hydrocarbons

Execution of educational films for students with dysfunction of hearing and speech was also possible through the use of digital techniques. They enabled the simultaneous placement in the frame image of a sign language interpreter, computer animation, subtitles and logos and film sequences that required the use of computer software for the pursuit of special effects in movies. Execution these films using a digital camera require separate registration of chemical experiment course and registered separately image of a sign language interpreter, and then impose his image on film sequences of chemical experiment. On the results of surveys conducted among students of deaf and mute and hard of hearing in both high school and in secondary school can be concluded that these films help them learn chemistry. In the opinion of the students rate of information transmission is relevant to the perceptual abilities of most students [87%]. These are the first educational films with chemical experiment, using a sign language interpreter. Students with dysfunction of hearing and speech emphasized that the introduction of the translator made it much easier for them to understand the issues presented and to prepare for the experiments in the laboratory [Jagodzinski, 2012 b, p.1122].

Currently popular is the registration of dynamic images in high resolution called FullHD [Full High Definition]. This gives amazing results of crisp images, on which can be seen much more fine details and contours of registered objects are clear and sharp. Thanks to these properties realized educational films take on a new meaning. Using these possibilities was prepared educational program Multimedia lexicon of chemistry experiments [Jagodzinski, 2012 c, s.371]. The program includes 60 films illustrating the chemical experiments devoted to application of chemical reactions and chemical substances in improving the quality of human life. Prepared films can be used multivariant. They can be used for chemistry lessons in high schools as an illustration of the discussed issues. In another case, they can be used in the education of students preparing to become science teachers.

Films were grouped into six thematic sections: Mineral Treasures of Earth, Chemicals in agriculture, Chemistry, and our health, Chemistry of packaging and clothing, Cleaning chemicals, Energy today and tomorrow.

Studies were conducted which aim was to determine the educational usefulness of realized movies. Prepared films were the basis for the formulation of a research problem. When solving the problem they were used in different stages of the cognitive process of students. It was assumed that by analyzing the experimental results presented in the movies, you can get new knowledge, and learn about new descriptions of phenomena. Experiments in the prepared films were the main means for getting to know the properties of substances. Allowed for the collection of experimental data and their classification. Also was conducted research concerning effects of film instructions for chemistry experiments discussed above, on the growth of cognitive and practical skills, that is better knowledge of the design and execution of basic techniques of laboratory work by students.

The results of pedagogical research suggests that a set of videos with experiences in the Multimedia lexicon of chemistry experiments is useful from didactic point of view, so it can be successfully used on chemistry lessons.

Educational Videos in 3D system and studies of their impact on chemistry learning effectiveness

3D movies create the illusion of volume and space by double projection - one for each eye. Special tooling filters and isolates the light passing the image intended for one eye, from the image intended for the other eye. Digital visualization techniques have enabled more precise than before matching left and right images, providing a pleasant experience gained from viewing 3D images [Mendiburu, 2009].

How is created the illusion of three-dimensional image?

Stereotopsy is human ability to combine two separate images, delivered to the brain through the eyes and for reading surround newly formed image. This is one of the many ways by which we perceive three dimensions of surrounding reality.

The situation is different in case of monoscopic spatial perception. This perception is possible due to a single vision, often using time shift. In turn, stereoscopic signals are received by a combination of the two points of view for each of the two eyes [Steve, 2006]



Fig. 16. Shutter Glasses for viewing stereoscopic 3D dynamic images

There are several technologies that enable to create a stereoscopic three-dimensional effect from flat conventional two-dimensional image. For this purpose serve filter glasses [for viewing anaglyph] glasses with alternate display of frames [active shutter glasses], polarizers and HMD displays [in glasses or helmets]. The base of spatial vision is different, because it is from two different points, seeing objects by both eyes. Simply put, have to be presented to the right and to the left eye of the observer different, though very similar to each other images of the object or the environment. Minor differences between these images arise from the fact that the right and left human eye can see the environment from different angles [Zone, 2012].

Chemical experiments in 3D films

Use of 2D and 3D films is useful on chemistry lessons especially in those cases where is not possible in a school laboratory conditions, the implementation of relevant experience illustrating a specific chemical transformation. Also, when the execution of the experiment is not possible because the reaction occurs too quickly or too slowly [McGrew and LeRoy, 1972].

3D visualization in chemistry education, including 3D films, is a high-quality teaching resource, which in increasingly more faithful way reflect, learned by learners reality. They allow students to gain knowledge in conditions very close to natural [McGrew and LeRoy, 1973].

In the case of close shots in 3D films depth effect is gaining momentum. For example, a set of laboratory reaction flask fills almost the entire lab, which dramatically increases the emotional charge of recognition. Increasing the realism of blood and sets of laboratory equipment appearance for 3D movies has a positive effect on the cognitive process and the presentation of the experiments course.

The composition of the image is not the only factor which must be carefully adjusted to the third dimension. Also important are assembly rate and visual effects, which need special attention. Due to the increased visual complexity and prolonged absorption, 3D images require a more precise and skilful mounting style than in the case of 2D movies [suitsand Sanger, 2013]

Researches were conducted on the effectiveness of educational films recorded in 3D system representing the course of chemical experiments. These films concerned preparation of oxygen from the manganate(VII) solution; sulfur coal combustion and magnesium in oxygen,; preparation of carbon monoxide(IV); receiving of hydrogen in the reaction of zinc with hydrochloric acid; The law of conservation of mass; receiving of hydrochloric acid by dissolving hydrogen chloride in water; receiving of the salt by acid treatment to alkali; receiving of ethane and ethyne and studies on their properties and Tollens' test. Next films concerned issues related to relation of phosphorus(V) oxide with water; reaction of copper nitrate(V) of silver(I); study of activity by Daniell cell; study of temperature influence on the gas solubility in water; catalytic synthesis of magnesium iodide; catalytic decomposition of hydrogen peroxide; study of properties of ammonia; influence of substrate concentration on the rate of a chemical reaction; sludge precipitation of sparingly soluble salts and the temperature influence on the rate of chemical reaction. In the study were involved 25 secondary school students and 25 high school students. There were three groups of students at each level of education. The first group of students before performing experiments in the school chemistry laboratory used the film instructions for chemistry experiments recorded in the 2D system. The second group of students before performing experiments in the school chemistry laboratory used the film instructions for chemistry experiments recorded in the 3D system. The third group of students used alternately film instructions from 2D film, and film instructions from 3D film. Was observed how students from each group handle different experiments during work in laboratory and what results they achieved in the final test and the spacer test. A reflection of student achievement of particular groups are the results of the growth of their knowledge and the results of the survey. Was also determined the effectiveness of educational 3D movies in chemical education. On questionnaire answered also 25 involved in the studies second-degree students of the Faculty of Chemistry, Adam Mickiewicz University and 28 middle school and high school science teachers. These teachers were participants of laboratory teaching in chemistry subject as a participants of postgraduate studies of the Faculty of Chemistry, Adam Mickiewicz University, raising their professional qualifications. Educational effectiveness of 3D films is the difference in knowledge increment value of learners using 3D films and learners using 2D movies. The study was conducted in the four categories taxonomy of learning objectives B.Niemierki, it is: A - remembering the information, B - understanding the information, C - the use of knowledge in typical situations, D - application of knowledge in problematic situations. This taxonomy is consistent with the taxonomy of learning objectives B.Blooma, but is particularly well suited for chemical education [Bloom, 1956; Anderson and Krathwohl, 2001]



Fig. 17. Students working with film instructions for chemistry experiments recorded in the 3D system



Fig. 18. Students while solving the final test

Below are presented questionnaire questions that uses a five-point Likert scale, which has resulted in response to the degree of acceptance of the presented ideas.

Here are the survey questions:

1. While watching the course of chemistry experiments recorded on films in 3D technology I remembered more details than when watching the course of chemistry experiments recorded on film in 2D technology.

2. After familiarizing myself with the instructions for chemistry experiments recorded on films in 3D technology I have cutted the respective sets to perform these experiments in the school laboratory committing less errors than after hearing the instructions for chemistry experiments recorded on the films in 2D technology.

3. Multimedia instructions for experiments on 3D movies are more demonstrative than the instructions on 2D films and therefore I better understand the discussed chemical issues.

4. Thanks to chemical experiments observed on 3D movies I'm better at solving chemical problems, similar to the problems discussed earlier on lessons, substantively related to the content of these films than in the case of the same experiments observed on 2D films.

5. Thanks to chemical experiments observed on 3D movies better I'm better at solving chemical problems than in the case of the same experiments observed on 2D films.

6. Watching the course of chemical experiments recorded on films in 3D technology makes me more eyestrain than watching the same films made in 2D technology.

7. Watching the course of chemical experiments recorded on films in 3D technology increases my emotions associated with the experiencing of what is happening on the screen compared to the excitement generated while watching the course of chemical experiments recorded on the films in 2D technology.

8. Thanks to the films in 3D technology, presenting chemical experiments, while learning chemistry seems to me that I actually take part in performing watched experiences.

9. Introduction to chemistry learning 3D films with chemical experiments resulted in my greater interest in learning chemistry.

10. Introduction to chemistry learning 3D films with chemical experiments did not affect the increase of my educational/learning achievements in chemistry subject.

Here is a set of answers, beneath each survey question, arranged according to a Likert scale, from which students could choose one answer, consistent with their opinion:

With the above statement:

a I strongly disagree, b I rather disagree, c I have no opinion, d I rather agree, e I strongly agree.

Summary of test results.

Tab. 2 Results of the survey

	students																			
	secondary school high school				university students teachers															
	[%]																			
question	a	b	с	d	e	a	b	с	d	e	a	b	с	d	e	a	b	с	d	e
1	8	4	8	56	24	0	17	8	58	17	3	17	14	57	9	4	4	4	52	36
2	8	8	36	24	24	8	8	17	58	8	3	11	29	51	6	4	4	8	40	44
3	8	8	16	40	28	0	25	8	25	42	0	17	11	51	17	8	4	0	44	44
4	8	20	16	40	16	8	8	25	42	17	0	20	17	49	14	8	4	4	52	32
5	0	24	20	40	16	17	0	17	42	25	3	17	26	43	9	8	0	12	40	40
6	8	0	12	16	64	8	17	8	25	42	3	14	3	31	49	0	4	8	44	44
7	20	12	8	28	32	0	8	0	58	33	0	9	6	49	37	0	4	0	32	64
8	8	12	24	32	24	8	0	0	50	42	0	9	9	43	11	4	4	4	24	64
9	12	20	16	36	16	8	0	50	17	25	0	17	29	40	14	0	0	8	60	32
10	16	12	52	16	4	0	33	42	8	17	9	26	34	26	6	24	36	36	0	4

Tab. 3. The results of educational research on students' knowledge growth and educational effectiveness of 3D films in the studied groups of learners

-		categories in taxonomy of educational objectives							
-	type of films	type of films A B C							
	type of filling	increase in educational achievements [%]							
	2D	52	47	35	23				
high school students	2D3D	58	52	38	28				
	3D	63	56	44	34				
university	2D	38	33	28	25				
	2D3D	43	40	33	28				
	3D	47	45	39	32				
		educational effectiveness [%]							
high school students	3D – 2D	11	9	9	11				
	3D-2D3D	5	4	6	6				
university	3D – 2D	9	12	11	7				
students	3D-2D3D	4	5	6	4				

Based on the results of the survey [Table 1] it can be concluded that the inclusion of 3D films into the educational process brought positive results. The majority of respondents in all groups of learners declared that thanks to watching 3D films remember more details and commit fewer errors when mounting the proper sets to perform experiments. The majority of respondents stated that multimedia instructions for experiments recorded on 3D movies are more demonstrative than the corresponding 2D instructions. In the case of secondary school students and in case of students 3D films to a lesser extent, affect the ability to solve common and new chemical problems than in the case of high school students and teachers, where you can see a more beneficial effect of three-dimensional images on the ability to solve these problems. The high school students, university students and teachers said that while watching 3D films they have the impression of

real participation in performing of experiments and it was accompanied by greater excitement than in the case preparation for performing experiments using manual 2D film. For secondary school students, many of them did not report such an impression. The use of 3D films in the opinion of all groups of examined participants resulted in their increased interest in learning chemistry and resulted in an increase of their achievements chemistry subject.

Survey results [Table 1] were reflected in studies on growth of learners knowledge and effectiveness of educational instruction film for chemistry experiments recorded on film in 3D system [Table 2]. Both groups of high school students and university students who have worked with 3D film instructions showed a better achievements in each category taxonomy of ,learning objectives. It was observed that with the increase in the educational value each category taxonomy of learning objectives was followed by a decline in educational achievement. It was, however, smaller than in the case of groups of students working with a 2D film instructions. In the case of control groups students working alternately with 2D films and 3D films results are as close to the median value of the results obtained by the group of students working with the 2D and 3D movies instructions. The results therefore indicate that the instructions for chemistry experiments recorded on films with a 3D system influence greater effectiveness of chemistry teaching than the corresponding film instructions recorded in a 2D system.

Summary

The development of technical means of communication has always inspired educators to support and modernize educational process. The use of new transmission technology of video and sound gives special advantages in experimental science and science teaching subjects. Today, teacher can, in many cases create by himself needed to teaching resources and influence the process of teaching-learning like never before. Everything will depend on his ability and creativity and skillful use of didactic aids in accordance with the principle of multilateral training.

Author of the article for almost 30 years is the creator of didactic aids supporting the implementation of issues related to the chemical experiment. Over these years we observed the development of technical means of communication and new learning technologies utilizing their capabilities and advantages for the implementation of educational videos and multimedia computer programs. The results of studies on the effectiveness of prepared educational didactic aids allow us to conclude that they have a significant impact on improving the quality and efficiency of education across all categories of taxonomy of learning objectives in chemistry learning.

Prospects for the continuous development of video recording technologies are very promising. This technology allows to make more and more devices with multiple functions, enables to increase interactivity between the application user and a given application. This can be successfully used in modern education. The development of imaging method in order to better assimilation of teaching material, stimulating the spatial imagination of learners through the creation of videos and photos in 3D three-dimensional technology, the upcoming era of flexible polymer screens enabling their rolling and moving in pocket and devices called spatial printers [3D printing], allowing for receiving blocks, so models of objects with all their details [http:// en.wikipedia.org/wiki/3D_printing] will cause the continuous development of teaching methods and create new opportunities to conduct research on using them in education.

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Piotr Jagodziński

Department of Chemical Education, Faculty of Chemistry, Adam Mickiewicz University, Poznań, PL

piotrjot@amu.edu.pl

LABORATORY WORK SUPPORTED BY COMPUTER SIMULATION IN SECONDARY CHEMISTRY INSTRUCTION: A CASE STUDY

Veronika Machková, Martin Bílek

Introduction

In chemistry instruction, computer models are considered good means to enhance traditional expository lessons as well as to support laboratory work [Smetana & Bell, 2012]. Multiple studies focus on using computer simulation as a mean to introduction to real laboratory activities [Burewicz & Miranowicz, 2006, Winberg & Berg, 2007]. Researchers conclude that the simulation supported pre-lab activities lead to better comprehension of the technique and basic concepts used in laboratory work to improving content knowledge, as well as to increase interest in the course [Rutten, van Joolingen & van der Veen, 2012].

In chemistry instruction we work with objects and phenomena on three different levels. Johnstone [1993] specifies the macroscopic, microscopic and symbolic levels. According to Johnstone [1993], chemists work inside this triangle. Le Maréchal and Bécu-Robinault [2006] define the triangle in another way, they understand the simulation to be an intermediator between the theoretical, observable and reconstructed world. They state some facts on the theoretical level are of objects quality (e.g. atoms, molecules, ions) which belong to this world, and the learner should construct the imagination on them. In computer simulations one concept can be expressed in various ways respecting three levels of chemical phenomenon representation and each expression presents specific information about the concept. To make the concept meaningful brings the understanding and being the whole set of expressions on three different levels of representation in mutual accord [Tiberghien, Buty & Le Maréchal, 2003].

Various types of activities are integrated in electronic learning objects. It provides the possibility to create such a learning situation where electronic learning objects can be handled by a learner or a small group of learners. Under such conditions the computer model can be an important source of information and the environment where the learner acts, solves the problem situation tasks, tests hypotheses etc. [Bell & Smetana, 2008, Beaufils & Richoux, 2003]. The responsibility for learning and collecting information is thus transfered on the learner. The teacher's role is changing; the teacher is becoming the guide introducing such situations which evoke learner's (group of learners') activity in a selected environment. And this activity (confrontation of starting learner's knowledge and the computer model reaction) consequently leads to construction of knowledge [Tiberghien, Buty & Le Maréchal, 2003, El Bilani, 2007]. This learning situation is called "adidactic", where the fourth element (environment) is implemented in the classical triangle (learner – teacher – learning content). The learner constructs new knowledge in the interaction with the environment which evokes the state of contradiction, problem or disbalance to the current state of knowledge. Under such conditions the learner does not expect to be taught as in the expository lesson lead by the teacher.

Research Project Design

Our research activities focus on researching ways how computer simulations of acid-base titrations can be implemented in the process of instruction. We decided to analyse in details learners' interaction with the computer simulation in the autonomous learning situation. We expected the work with the computer model will support forming relations among the three levels of knowledge, as specified by Le Maréchal and Bécu-Robinault [2006], i.e. the theoretical – observable – reconstructed world. In case of acid-base titration the use of computer model was expected to provide impact on forming the relation between the course of titration (the observable world), changes in pH values of the solution (the reconstructed world) and the graphic course of

titration curve (the theoretical world). Further on, we expected the learning situation combining learners' activities directed by the worksheet and by the computer model working as the main source of information for learners would enable to change the traditional approach to laboratory work into autonomous and independent work of learners towards constructing new knowledge.

The survey was conducted in the group of 16 students in the course of Selected Laboratory Methods in the fourth year of Secondary Medical School. For the research two pedagogic scenarios for laboratory work were designed where theoretical tasks supported by computer simulations and by real experimental activity of learners were solved. Learners worked in pairs following the instructions of the worksheet. They were to solve the task, agree on the results and write it down to the worksheet. Production of verbal comments of one pair of learners on the work with the computer model and during the laboratory work was recorded by digital recorders. The reference source of data were didactic tests of pre-test – post-test – retention test schema.

The analysis of verbal audio-recording of a pair of learners when working with the computer model and running the real laboratory work was structured into several steps – segmentation, coding, commenting (by the researcher when analysing the recording) and detecting relations and interpretation [Skutil, 2011]. The recorded verbal comment production of learners was transcribed and structured reflecting topics (segmentation) and single parts of the worksheet. Each expression was marked by a symbol (coding I) relating to the expected actions (A=learner reads the task, B=learner works with the computer model or titration apparatus, C=learner solves the task from the worksheet, D=unexpected situation). With the C-type expressions we focused on what levels of knowledge were connected and related (coding II). The categories within the analysis were defined by the level of knowledge stated by Le Maréchal and Bécu-Robinault [2006], see above. The method of data collection and analysis reflected the research design analysis applied studies by El Bilani [2007] and Rodrigues [2007].

Results

In the analysis of verbal comment production in single segments we summarized the levels of knowledge used by learners. When solving theoretical tasks supported by computer simulation in both designed lessons, totally 526 expressions were detected; learners used the observed categories 180 times. The frequency of expressions reflecting single levels of knowledge and mutual relations between them are displayed in fig. 01. The most contributive to acquiring chemistry knowledge are expressions connecting various levels, i.e. those situated in the intersection of the three fields. It means the different levels were connected in 46 expressions.



Fig. 01.

When solving practical tasks in both designed lessons, totally 166 expressions were detected where the observed categories were used 40 times. We suppose the higher occurrence of expressions in theoretical than practical tasks resulted from higher level of learners' cognitive

activity. In practical tasks learners more concentrated on the preparation of workplace and manipulation with the titration set, which resulted in lower frequency of expressions. That is why we think the prepared theoretical tasks solved with the help of computer model could work as appropriate support to practical experiment of acid-base titration and help learners to develop knowledge which cannot be acquired within the experiment only.

New knowledge was nearly entirely acquired autonomously in solving tasks set by the worksheet with teacher's minimal support in real time. Teacher's interventions were not frequent; they mostly helped with managing the computer model, understanding the task, preparation of the workplace or working with the titration apparatus and pH-meter. The help in solving theoretical tasks was required by one pair of learners only. The frequency of teacher's interactions was lower in the second designed lesson (from 11 to 2 in the theoretical part and from 11 to 3 in the practical part). This results leads us to conclusion that using the experience from the first observed lesson learners worked more independent in the second one, both in solving theoretical and practical tasks.

Above all, the previous level of knowledge played the important role in work with the computer model. Reflecting the previous knowledge the observed learners explained in discussions how the computer model works, defined how it would behave, they contradicted simulated characteristics of objects in the computer model interface, in case of various levels of knowledge they provided specifications.

Within the course of instruction learners went through situations defined in worksheets, and which we expected. Instead of those, several unexpected situations appeared. First, some situations produced negative impact on learning, and teacher's intervention was required. These situations related to problems with working with the computer model and understanding the task but they were not too frequent. Second, the unexpected situations brought positive values, as learners defined their own hypotheses and immediately verified them by the computer model, contradicted them and provided additional information we expected they had acquired before.

Conclusion

In this research survey the analysis of interaction of learners working with the computer simulation in autonomous learning situation within two lessons of laboratory work focusing on acid-base titration was presented. For this purpose we designed learning units with the computer model support in which we combined theoretical tasks with computer model simulation and a practical task. The analysis of verbal communication production of a selected pair of learners and their results in didactic tests on the pre-test - post-test - retention test structure showed the designed schema of learners' independent work with learning computer model directed by the worksheet lead to acquiring new knowledge and its implementation into existing knowledge structures. The process of acquiring the new knowledge ran by way of learners' interaction with learning computer model, the knowledge was based on observation of the learning computer model behaviour, defining expectations (hypotheses) and verifying them on the model and evoking problem or contradicting situations. Our results verify to large extent those presented by Plass et al. (2012) who stated that within the interaction with the simulation learners were involved in the process of scientific thinking (e.g. defining the problem, setting hypotheses, experimenting, observation, data interpretation). Within the observed units and learners' work with the learning computer model the teacher performed the role of consultant supporting learners in difficulties. The help was crucial in identification of simulated objects within the first designed lesson containing theoretical tasks with both the computer simulation and real experiment. Further on, learners were able to shift (rather without problems) from the didactic situation to "adidactic" one (see above). Within its course they proved motivation to numerous activities which experimental activities aimed at. Reflecting the research results by Bilek et al. [2011] we can expect even wider possibilities of the principal insight in the researched problem than they were detected in traditional real experimenting (using instructions for running the practical laboratory task.

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Veronika Machková, Martin Bílek

University of Hradec Králové, CZ

veronika.machkova@uhk.cz, martin.bilek@uhk.cz

THE USAGE OF VIRTUAL LABORATORIES IN TEACHING FIRST YEAR STUDENTS OF BIOLOGY

Justyna Cegła, Małgorzata Nodzyńska

Introduction

The usage of virtual laboratories has been becoming more popular, especially in Western Europe. It is used on all stages of chemistry education, even on academical level. There are many on-line laboratories that have been created with support of universities. Those laboratories are used to certain extent in courses offered by those universities. Some of those laboratories are publicly available. Other can be accessed after logging in as a participant of aforementioned courses or after paying predetermined fee.

The goal of this research was to find out whether first year students of biology "will like" conducting chemical experiments on-line, and if they prefer this method over traditional laboratory work.

Theoretical part

"Supporting teaching of subject by using experimental work of students is specific to science subjects" [Galska-Krajewska & Pazdro, 1990]. "The development of chemistry as a field of science in a second half of XXth century has led to the rise of the notion that course of education in natural sciences (including chemistry) should be similar to research process conducted by scientist. It should also be connected with researches carried out by teachers and pupils" [Paśko & Nodzyńska, 2012]. In addition, chemical experiments are one of the basic methods of activation in the teaching of chemistry, because students learn through their own action, as is in the laboratory experiments [Paśko & Nodzyńska, 2012].

Classification of chemical experiments according to Burewicz & Gulińska:

- "Illustrative experiment – teacher informs students about aims and methods of execution of the experiment and gives out observation and conclusions.

- Research experiment – teacher directs the course of the experiment. However, students write down observations and draw conclusions on their own.

- Problem experiment – students plan, conduct and solve the problem without teacher's direct help. [Paśko & Nodzyńska, 2012]

Chemical Experiments are one of the most important methods of teaching Natural subjects, especially in teaching Chemistry, which is experimental science. Experiments play central role in teaching of that particular subject. It is important that students "become a scientists" during chemistry lessons as it creates great cognitive opportunities. By doing researches students can independently gain knowledge. Moreover, experiments affect intellectual development of students and help them remember and gain better understanding of occurring processes. This not only allows independent observation or drawing of conclusion, but also it helps student with better comprehension of certain process. "Thanks to experiments students start to notice particular type of organization in diversity of matter. They learn to think critically while concerning the results of the research as well as methods of searching and verifying those results. Students are taught orderliness, responsibility, compliance with health & safety rules. But they will also feel the need for planning their future actions and finding the answers to their question.

Unfortunetly, it is not always possible to perform an chemical experiment. The cause may be lack of necessary chemical reagents, laboratory equipment, especially in schools which do not posses sufficient funds to properly equip school laboratories. Another reason for that may be lack of time to perform experiments, as many of them exceed the time of single lesson unit. As a result

it would be impossible to convey necessary information for such experiment. Another common issue is safety. Lack of knowledge about properties of certain substances could be potentially dangerous. According to Paśko [2003] increasing number of students fear direct contact with chemical reagents and as result the interest in performing individual experiment by students is decreasing.

The consequence of that may be discouragement of students towards the subject in question, as many teachers, as a way of dealing with the problem, turn to simply describing the experiments or presenting them without participation from students. The discussed material is less comprehendible and often less appealing.

Subsequently, chemistry becomes more of a verbal science, which disfavors process of learning and gaining new abilities. In most cases "the picture" is easier to comprehend than the verbal description of an item. That's why, in order to replace the chemical experiment, new methods are seeked [Paśko, 2003]. It's one of the reasons why performing an experiment is replace with film projection. However, this method does not activize students enough. Usually, students are showed just one instance of experiment. Because of that students are familiarized with just one possible outcome of chemical reaction. They are unable to check whether the particular reaction would proceed differently if the substrates or conditions had been changed. So the independent and individual performance of experiments by students is crucial and such experiments should be conducted as often as possible. Virtual laboratories make this possible.

Virtual Laboratories

Internet is full of platforms that include virtual laboratories as part of their services. They allow conduction of many experiments, with usage of many different reagents, which allows students to analyze possible outcomes of a particular chemical process. This is furthermore advantageous because to perform such experiment students do not require laboratory, equipment, reagents. It is also safer than conducting real experiment [Paśko & Nodzyńska, 2007].

The benefits of experiments conducting computer programs:

- Possibility of analyzing different chemical reactions while choosing many different chemical reagents and laboratory equipment,

- The preparations and execution of such experiment takes little time compared to real life experiments,

- The individualization of education because students plan and conduct experiment on his own,

- Safety – students can perform tasks which in real life situation (given the lack of precision) could be hazardous,

- Compared to the real-life laboratories, virtual ones are cheaper,

- More precise discussion of results and conclusions (as a result of quicker execution of virtual experiments),

- The ability to conduct more experiments per lesson unit.

Unfortunetly, in Poland only few analyses concerning virtual laboratories have been carried out. One of such surveys have been conducted in culturally similar Czech Republic [Bilek, 2010] on elementary school students. Those student were divided into two groups. One of them worked with virtual pH-meter. The other group used real one. Both groups received same instruction concerning the execution of the experiment. After completion of given task, students filled out surveys. It turned out that students prefer to work with real pH-meter. Moreover, students that have been working in traditional got better results in following didactical test.

Methodology of research

The main goal of carried out research was to examine whether approach of using on-line laboratory as a replacement for real laboratory work is considered engaging by the students.

Nowadays using teaching methods based on virtual programs is quite popular. Today's youth

feels at home with this kind of working environment. It comes to them so naturally that they can be called "digital natives", who are "born and shaped" in completely different informational environment and are, in some educational aspects, distinctly differentiable from their parents. These differences run deep: to parts of the brain which are shaped in a preschool period. They are and will continue to be different, similarly to how distant and unpredictable will be their future world to us. So consequently a new problem arised: will those "digital natives" be able to conduct experiments using computer programs and virtual animation and whether this method would get their approval.

Another, equally important, aim of aforementioned studies was to check to what extent can the traditional laboratory method be replaced by the on-line laboratories. It was also decided to investigate is it possible to replace real laboratory courses with virtual ones (having taken into consideration recent trends in education and development of new teaching methods). Such replacement would greatly reduce costs connected with maintaining laboratories as virtual courses do not require reagents or expensive equipment.

Methods of Research

The study was conducted on a group of students of first year of biology. It lasted for a period of thirteen weeks, from October 2013 to January 2014. At the beginning of the course there were forty four students. At the end – twenty two remained. The research was done by e-learning platform of Pedagogical University in Kraków as a part of "general and analytical chemistry" course. As a way of preparation for laboratory classes participants were to familiarize themselves with: theoretical introduction concerning particular exercise (The necessary literature/information was available on the aforementioned platform), procedure for the performed experiment. Afterwards they had to carry out an on-line experiment. 9 laboratory classes were planned and appropriate amount of instructions and experiments were prepared.

Tab.1 Topic and number of the exercise for which the instructions were prepared (the given number is corresponding to the number on the platform).

Class II - "Calculation of volume percent and molar concentration of water solutions.

Preparation of solutions with desired concentration by dilution of those solutions.

Class III – "Bronsted-Lowery theory of acids and bases, indicators, sensitivity of chemical reaction. Nomenclature of acids and hydroxides.

Class IV – "Methods of obtaining salts, nomenclature of salts. Micro reactions (chemical reactions observed under microscope, crystals. Solving stoichiometric exercises.

Class V - "Nomenclature of Coordination complexes. Amphoterism

Class VI – "Calculation of the pH of aqueous solutions of salts. Identification of salts in aqueous solutions. Class VII – "Introduction to quantitative analysis. Making calculations based on results of titration. Acidbase determination of the percentage of sodium hydroxide or potassium hydroxide in aqueous solution." Class XII – "Oxidation and reduction reactions. Manganometry. Determination of the percentage of oxalic acid or potassium oxalate in aqueous solution."

Class XIII – "Iodometric determination of the percentage of Na₃AsO₃, NaAsO₂, or in aqueous solution. Complexometric determination of calcium content (in grams) in aqueous solution. "

After completion of the online experiments, students performed carried out same experiments in university's laboratory in real world. Following the classes students filled out surveys (located on the on-line platform) which evaluated the efficiency of on-line experiment. Participation in on-line experiments on the platform was voluntary.

The main objective of studies was to find out, if it is possible to replace traditional laboratory method and whether students would like it.

The surveys were prepared using Google.Doc tool. The survey consisted of multiple choice - single answer part, open-ended questions and Lickert's Scale. The finished form was located

on Moodle platform (attached to all exercises). After completing the questionnaire students sent their results directly into a spreadsheet, where all the results were collected. Spreadsheet then performs independent analysis of the collected data [Bodnicki &Regulska, 2011].

Tab. 2 Questionnaire's form



Instruction for students for individual exercises.

Instruction for Class II – "Calculation of volume percent and molar concentration of water solutions. Preparation of solutions with desired concentration by dilution of those solutions".

Click on the link: ://chemcollective.org/activities/vlab?file=&lang=

Using virtual laboratory to make10% solution of sodium chloride.

To do so: Look for the button "solids" located in reagents menu ("stockroom explorer) which can be found on the left side of the window. Once you found it double click on it.

In this subcategory you should find jar with NaCl. Now double click on the "distilled H_2O " button. After you've done that the container containing H_2O should appear in "workbench" window.

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Conjugate-acids	4		
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Fig. 1 The main screen of "ChemCollective" program

Following that, click on the icon of laboratory glassware (

Use first one to prepare the given solution.

Use remaining beakers to dilute earlier prepared NaCl solution. To do this you need to:

- Fill the second and third beaker with 5cm3 of prepared NaCl solution

- Pour 5cm³ of distilled water into second and third beaker

- Fill the third beaker with 10cm³ of water

- The fourth one should be filled with 5cm^3 of solution from the second beaker, following that pour another 5cm^3 of water.

Calculate volume percent of diluted solutions.

Calculations necessary for preparation of solutions

Use the Volume percent formula $C_p = (m_s/m_r) \cdot 100\%$

Consider how much of the given solution you want to prepare.

You may assume that density of water equals to 1g/cm³

After transforming the formula, calculate the mass of the substance $m_s = (m_r \cdot C_p)/(100\%)$

After you finish calculating the mass of the substance. Calculate the volume percent of the diluted solution.

Calculating concentration in beakers 2,3 and 4:

Solution's concentration in beaker 2:

There's 5cm³ of 10% solution of NaCl in beaker 2 so $m_s = 5g$

Knowing mass of the substance you can calculate voulume percent of solution after adding 5g of water.

 $C_p = 5g/10g \cdot 100\%$

$$C_{p} = 5\%$$

The concentration of solution after dilution is 5%

Perform calculations for beakers 3 and 4 in similar fashion.

Instruction for Class III – "Bronsted-Lowery theory of acids and bases, indicators, sensitivity of chemical reaction. Nomenclature of acids and hydroxides".

Click on the following link: http://chemcollective.org/activities/vlab?file=&lang=

Open four new tabs (called "workbench") in virtual laboratory by pressing "File" and then "New workbench".



Fig. 2 Main screen of "Chemcollective" program

Repeat the process until you have four "workbenches"



Fig. 3 The "laboratory" screen of ChemCollective program

In the first tab ("Workbench 1") choose strong acids by pressing "Stockroom Explorer"=>"Strong acids". Next, choose 3 molar hydrochloric acid, then choose 3 molar sodium base by pressing "stockroom explorer"=>"strong-bases".

Check the pH of those solutions (you can check pH on the pH-meter in the bottom right corner of the screen.

Afterwards, choose the indicator from the list of the available reagents. To do so click on the button titled "Indicators" and choose the bottle of methyl orange. Once you have all the reagents, choose two 250ml beakers from the laboratory equipment.

Fill the first beaker with 10ml of acid, and pour 10ml of base into the second beaker.

Following that, add 0,5ml of methyl orange into both of those beakers. Check the color of the solutions.

Instruction for Class IV- "Methods of obtaining salts, nomenclature of salts. Micro reactions (chemical reactions observed under microscope, crystals. Solving stoichiometric exercises".

Click on the following link http://www.chem.ox.ac.uk/vrchemistry/livechem/transitionmetals_content.html

Follow the instructions.

Laboratory is divided into two categories of reagents: those placed in the upper part of the screen – those are salts of metal cations. At the bottom of the screen you can find reagents that can be used to react with salts.

Pick zinc and copper salt(II).



Fig. 4 Screen of the virtual laboratory of "Live" Chem" program

After you've done that, press "Play Movie" and observe the ongoing reaction. Write down your observation and draw conclusions.

Then, press "Reset" button.

Now choose "Mg Turnings" and iron salt (III). Press "Play Movie" button and observe the reaction. Write down your observation and draw conclusions.

Instruction for Class V: "Nomenclature of coordination compounds. Amphoteric."

Click on the following link: http://www.chem.ox.ac.uk/vrchemistry/livechem/transitionmetals_content.html

Using the virtual laboratory follow the instructions.

Choose zinc salt from the cation salts tab. Then, select ammonia from the reagents located at the bottom of the screen.



Fig. 5. Laboratory screen of "LiveChem" program

Afterwards, press the buttons and observe the ongoing reaction.

Write down observations, reaction equation and formulate conclusions.

Instruction for Class VI: "Calculation and measurement of the pH of the aqueous solutions of strong and weak acids and hydroxides".



Fig. 6. The experimental set - pH meter

Using the above animation follow the instructions.

In the lower left window, you have to choose the type of substance acid (acid), base (base), salt (salt I, II, III). First select the "acids" by checking the white dot at the "Acid". At the top, there will empirical formulas of different acids. Select one example like Sulfuric acid (VI), and in the lower right window choose volume (volume) of (volume) solution of the acid.

You can change it by moving the slider on the bottom blue line or by typing it the selected value. Select volume (for e.g.: 40ml). Afterwards select concentration (molarity) of solution . You can do it in similar way to selecting volume (moving the slider on the top blue line) or you can type in value of "0,00" and choose, by selecting white dot, appropriate conversion for e.g.: $x \ 10^{-3}$ mol/dm³, $x \ 10^{-2}$ mol/dm³... Select the molarity e.g.: $10 \ x \ 10^{-3}$ mol/dm³. To check pH of the solution you must dip into it electrodes of the pH meter. To do so, press "Insert probes" button and read the value of pH for the solution of sulfuric acid(VI).

Then, measure the value of the pH for potassium hydroxide. In order to do that, you must remove electrodes by pressing "remove probes" icon. Proceed as in the case of sulfuric acid(VI).

Examine whether the pH of the tested acid and hydroxide depends on the amount of the solution or the concentration (molarity).

Measure pH of any given acids and bases.

What determines the pH of the examined solution?

Instruction for Class VII - Subject: "Calculation of pH of the aqueous salt solutions. Identification of the salt in aqueous solution".



Fig.7. Experimental Set - pH meter

Using the above animation follow the instructions.

In the lower left window, you have to choose the type of substance acid (acid), base (base), salt (salt I, II, III). First select the 'salts' by ticking white dot at the "salt I', "II salt" or "salt III". At the top, there will be empirical formulas of different salts. Choose one of them, for example: Sodium chloride, and then in the lower right window, select the volume of saline solution. You can set it by moving the slider on the bottom blue line or by typing in the box the selected value. Select the volume for example: 40 ml. Then select the desired concentration (molarity) of the solution. You can proceed in the same fashion as with setting up the volume (by moving the slider on the top blue line) or type in value of 0,00 and choose one of the quantifiers for e.g.: x 10^{-3} mol/dm³, x 10^{-2} mol/dm³. Set concentration to 1 x 10^{-3} mol/dm³. To check pH of the tested solution you need to immerse into it electrodes of the pH meter. To do that press "insert probes" and read the given pH of sodium chloride.

Examine, wheter pH of tested salts depends on the amount of solution or it's concentration (molarity)

Measure pH of two unknown salts (Uknown II and Unknown IV) – Can you tell what salts are they based on the value of the pH?

Instruction for Classes XI - Topic: "Introduction to quantitative analysis. Calculations based on the results of the titration. Acid-base determination of the percentage of sodium hydroxide or potassium hydroxide in aqueous solution".



Fig. 8. Experimental set - acid-base titration

In order to complete titration on-line follow the instructions.

First pick type of reaction. To do that select type of reagents in step number 1 by clicking on the white dot (you can choose from titration of a strong base with a strong acid or a strong base with a weak acid), for this purpose: in step 1, click on the button next to "StrongAcid vs. Strong Base "or" WeakAcid vs. Strong Base ".

Afterwards, in step 2, choose what do you want to fill burette with. Select Acid (if you want acid) and Base (if you want base).

In step 3 choose appropriate acid and base by clicking on white dot next to empirical formulas of desired substance

In step 4 pick indicator. If you titrate base with acid you can choose from methyl red or bromothymol blue, if you're titrating acid with base then you can use methyl orange or phenolphthalein.

Afterwards, go to step 5. Here, by adding a drop of substance you titrate by clicking on the red button named "Dropwise" and watch out for the moment in which the solution changes the color.

Afterwards you read the value of volume of titrant used. Then you calculet molarity of the substance that you were titrating.

You write down your result in appropriate space in step 6 (type in 4 digits AFTER THE DOT, remember that in English-speaking countries you use . instead of ,) and then you press "OK". 104 If the results are positive, you can continue to next titration, if not – you must repeat this experiment.

You can start new titration by deleting previous actions (and you do that by pressing "RESET" button).

First complete the titration of strong base (NaOH) with strong acid (HCl) and then do the opposite. Afterwards perform titration of strong base (KOH) with weak acid (CH₃COOH) and vice versa.

Instruction for Class XII - Topic: "Oxidation and reduction reactions. Manganometry. Determination of the percentage of oxalic acid or potassium oxalate in aqueous solution".

In order to perform titrations on-line, follow the instructions.

First select the type of reaction. To do this, in step 1, select the reagents by clicking on the white circle (we can choose three types of reactions: manganometry, chromianometrie and iodometry).

Then go to step 2 here by adding titrant by clicking on the red button "Dropwise" carefully check the time for the moment in which the solution's color changes.



Rys. 9. The experimental set - redox titration.

Afterwards, write down the volume of titrant which was used. Then, calculate molarity of the substance that you were titrating.

Perform titration of the iron salt (II) with a solution of Potassium manganate(VII)

Instructions for Class XIII - Subject: "Iodometric determination of the percentage of $NaAsO_2$ or Na_3AsO_3 in aqueous solution. Complexometric determination of calcium content (in grams) in an aqueous solution".



Fig.10. The experimental set - redox titration.

To perform on-line titration correctly follow the instructions.

Firstly choose the type of reaction. To do this: choose reagents by clicking on the white dot in first step (we can choose three types of reactions: manganometry, chromianometrie and iodometry).

Then go to step 2. Here, by adding titrant by clicking on the red button "Dropwise" carefully check the time for the moment in which the solution's color changes.

Afterwards, write down the volume of titrant which was used. Then, calculate molarity of the substance that you were titrating.

Then perform titration of free iodine by aqueous solution of thiosulfate salt(VI).

Results

Discussion of the results of the studies for individual exercises/classes.

Class I Calculation of percentage concentration and molar aqueous solutions. Preparation of solutions of the desired concentration by dilution.

The questionnaire for the first exercise was filled out by eleven students.

First question:



Chart 1 Students answers to the following question "Did you have any difficulties with conducting and on-line experiment?". The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools]

Most of surveyed students did not have difficulties with executing experiments in virtual laboratory:

1 0 0%

2 1 9%

3 7 64%

4 1 9%

5 2 18%



Chart 2. Students answer to the question: "Have performing an virtual experiments had helped you with your work in real life laboratory?". The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools]

Most students answered that earlier work in on-line laboratory did not help with carrying out an experiment in traditional laboratory.





Chart 3. Students answers to the question: "Which method of work is more engaging for you?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

All surveyed students preferred working in traditional labolatory.

Fourth Question:



Chart 4. Students answers to question: "Were you able to execute the experiments correctly while working in on-line laboratory?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

Most students were able to perform given task correctly while working in virtual laboratory.

Fifth Question:



Chart 5. Students answer to question: "Do you think that you could use virtual laboratory method on different laboratory course?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

In this case both answers would receive the equal amount of votes if it wasn't for one more vote for the answer "NO".



Chart 6 Students answers to question: "Do you belive that traditional laboratory method can be replace by virtual method?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

All students think that virtual method cannot replace traditional laboratory labor.

Seventh Question: "Do you have any comments regarding the performed on-line experiment? If you do, please write it down".

Students comments regarding on-line experiments:

- " I have nothing to complain about",
- "they are time-consuming and I've got problems with launching the applications",
- "virtual laboratories does not work on my computer",
- "virtual laboratories should be available in Polish".
Judging by those comments, it is clear that the main problem was troubles with launching the application and The English interface of those programs.

Although only eleven students filled out the questionnaire, by checking results of logging in we could confirm that as much as twenty seven students conducted virtual experiments.

Class II "Theory of acids and bases BrønstedaLowergo indicators, the sensitivity of a chemical reaction. Combined acids and hydroxides".

The questionnaire for this exercise was only filled out by one person. This student did not enjoy working in virtual laboratory. However he believed that it helped him with work in traditional laboratory. He finds traditional experiments more engaging than virtual ones. Furthermore he disbeliefs that virtual laboratories could replace the traditional ones. He also thinks that virtual laboratory should be available in Polish.

After we checked the logging in numbers we concluded that 13 students participated in this virtual class. Even though they didn't answer the question we can be sure that they conducted the experiments.

Class III "Methods for the preparation of salt, salt nomenclature. Micro reactions (chemical reactions under a microscope) crystals. Solving stoichiometric".

Questionnaire concerning these laboratory was filled out by one person. He enjoyed carrying out on-line experiments and he believed that it helped him with work in traditional laboratory. He preferred virtual laboratory over the traditional one and also believes that it could replace the real laboratory in the future.

After checking results of logging in we confirmed that nineteen students completed this exercise. So we can conclude that even though they didn't answer the questionnaire they still performed the task.

Class IV "Nomenclature of coordination compounds. Amphoteric".

The survey for this exercise was filled out by ten students.

First question



Chart 8 Students answers to the following question "Did you have any difficulties with conducting and on-line experiment?". The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools]

Most of surveyed students did not have difficulties with executing experiments in virtual laboratory. So we can assume that the Polish instruction for the exercise was clear.



1		0	0%
2	2	3	30%
3	3	3	30%
4	l.	3	30%
5	5	1	10%

Chart 9 Students answer to the question: "Have performing an virtual experiments had helped you with your work in real life laboratory?". The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools]

As you can see, the students opinions are divided whether on-line laboratory helps in later work in the real, traditional laboratory. The same amount of students claims that the method is helpful/unhelpful and that is has no effect whatsoever. Only one student claimed that this method is not helpful at all.



Chart 10 Students answers to the question: "Which method of work is more engaging for you?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google. doc tools].

All surveyed students preferred working in traditional laboratory.



Chart 11 Students answers to question: "Were you able to execute the experiments correctly while working in on-line laboratory?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

Most students were able to perform given task correctly while working in virtual laboratory.

Fifth Question :



Chart 12 Students answers to question: "Do you think that you could use virtual laboratory method on different laboratory course?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

Majority of the students believes that virtual laboratory method cannot be used on different laboratory courses.

Sixth Question:



Chart 13 Students answers to question: "Do you believe that traditional laboratory method can be replace by virtual method?" The answers are shown in numerical and percental values. [The results of the survey were compiled using Google.doc tools].

All students think that virtual method cannot replace traditional laboratory work.

Seventh Question

"Do you have any comments regarding the performed on-line experiment? If so, please write it down".

Students comment concerning exercise IV:

- "they are time-consuming and I've got problem with launching the application",

- "I have no comments".

Similarly to surveys from preceding exercises students had problems with launching the application.

By checking the logging in statistics we can see that eleven students performed this exercise. It means that only one student, who conducted the experiment, did not feel out the questionnaire.

Class V "Calculation and measurement of the pH of the aqueous solutions of strong and weak acids and hydroxides."

Not a single student that has performed this on-line exercise has filled out questionnaire. But if we check logging in statistics we can see that twenty one students completed this virtual experiment. It can be said that the exercise was popular among students.

Class VI "Calculation of the pH of the aqueous salt solutions. Identification of the salt in aqueous solution".

Questionnaire concerning these laboratory was filled out by one person. This student preferred traditional laboratory over virtual one. He also thought that traditional laboratory could not be replace by on-line laboratory. Moreover, In his opinion, performing on-line exercise does not help with later work in real laboratory.

If we check number of people that logged in to perform this exercise we can see that nine students did so.

Class VII "Introduction to quantitative analysis. Calculations based on the results of the titration. Acid-base determination of the percentage of sodium hydroxide or potassium hydroxide in aqueous solution".

Questionnaire concerning these laboratory was filled out by one person. This student preferred traditional laboratory over virtual one. He also thought that traditional laboratory could not be replace by on-line laboratory. Moreover, In his opinion, performing on-line exercise does not help with later work in real laboratory.

He also had problems with completing the exercise. However, he believes that he could use this method on different laboratory course.

IF we check statistics we can see that only two students performed this particular exercise.

Class VIII "Oxidation and reduction reactions. Manganometry. Determination of the percentage of oxalic acid or potassium oxalate in aqueous solution".

Questionnaire concerning these laboratory was filled out by one person. This student preferred traditional laboratory over virtual one. He also thought that traditional laboratory could not be replace by on-line laboratory. Moreover, In his opinion, performing on-line exercise does not help with later work in real laboratory.

Student had no problems with finishing the task. However, he believes that he could not use this method on different laboratory course.

If we check statistics we can see that five students performed this particular exercise.

Class IX "Oxidation and reduction reactions. Manganometry. Determination of the percentage of oxalic acid or potassium oxalate in aqueous solution".

Questionnaire concerning these laboratory was filled out by one person.

This student preferred traditional laboratory over virtual one. He also thought that traditional laboratory could not be replace by on-line laboratory. Moreover, In his opinion, performing online exercise does not help with later work in real laboratory.

Student had no problems with finishing the task. However, he believes that he could notuse this method on different laboratory course.

IF we check statistics we can see that five students performed this particular exercise.

Summary of the results

Taking all results into consideration we can conclude that students did not find this particular method much to their liking. However, the reason for that may be low amount of filled out surveys.



Chart 14. Number of students that filled out questionnaires for particular exercises

Tab.3 Summary of all "yes" and "no" answers given by students concerning specific question of the survey

Question	Yes	No	The cumulative number of responses
Whether the execution of on-line experience made you any difficulty?	11	16	27
Have you managed, working on-line, to correctly perform the experiments?	20	7	27
Do you think that the virtual laboratory method might be used for other laboratory exercises?	12	15	27
Do you think that the traditional laboratory method could be replaced by virtual?	1	26	27

By looking at the "yes" and "no" answers given by the students for questions 1,4,5 and 6 we can see that virtual experiments were not troublesome to part of them (11) but most of students had difficulties with carrying out those experiments correctly. Despite this opinion. most of participants received correct results from experiments.

Some students (12) think that on-line method could be applied to other laboratory courses. Some of them think differently (15). Only one student believes that virtual method could replace the traditional experiments. On the other hand, twenty six students disagree and claim that traditional method cannot be replace by virtual method. This is crucial information which forces us to revise our assumptions.



Chart 15. Summary of the answers given for the 2nd question: "Have performing an virtual experiments had helped you with your work in real life laboratory?". – average grades given by students. (The average was calculated from the answers to the 2nd question. Exercise 5 was skipped because not a single student filled out the questionnaire after completing this class.)

On Chart 15 we can see that most of the students did not find virtual laboratories helpful in their later work in the traditional laboratory. Only in exercise 3 (the one concerning colors of the indicators in acids and bases) did students find this on-line experiment useful for their later work in real laboratory.



Chart 16. Summary of the answers given for the third question: Which method of work is more engaging for you?"

It is clear that students unanimously decided that traditional laboratory is far more interesting than virtual one.

While sharing their thoughts about virtual laboratories students often mention these issues: - Lack of Polish interface

- Problems with launching the application
- Conducting on-line experiments is time consuming

If we compare the ratio of students logging in for individual classes to the number of questionnaires filled out it is clear that most students decided not to partake in the survey.



Chart 17. Comparison between number of students conducting on-line experiments and number of questionnaires filled out.

Conclusions

After analyzing results of the survey, logging in statistics for individual exercises and following discussions with people responsible for leading the course we can conclude virtual laboratory method is not interesting enough for students of first year of biology. And as result it cannot replace the traditional laboratory classes. However, in some cases this method can help students with their later independent experiments. Furthermore, we can assume that virtual experiments can be used as an supporting method, instead of replacing the actual method.

It is also clear that one of the main drawback of this method for the students is the fact that it is published in English

Conducting research on e-learning platform can be considered a good method. Having said that though it has its cons. One of them is that only small percentage of students filled out surveys. As a result of that some of the results were lost. The ratio of students that filled out surveys to number of students that logged in to perform experiment is 27:112, chich gives us 24%. This means that only every fourth student, who used virtual laboratory, answered the questions in the questionnaire.

Conclusions regarding students reluctance towards working in virtual lab are crucial, because of ongoing trend in media of promoting and using virtual methods and so called "new media" as a means of working with pupils or students. Studies have shown that virtual laboratories cannot replace traditional labs. Taking that into consideration it would be unwise to depart from current methods of teaching in favor of new ones as it could be potentially harmful to the students.

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Justyna Cegła¹, Małgorzata Nodzyńska²

¹ - Zespół Szkół w Tczycy, Tczyca 177, 32-250 Charsznica

² - Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

THE USE OF THE MICROSCOPE FOR VISUALIZATION OF THE CHEMICAL PROCESSES IN THE TEACHING OF CHEMISTRY

Patrycja Pikuzińska, Paweł Cieśla, Małgorzata Nodzyńska

According to research conducted by PISA in 2007, almost 62% of pupils in Polish schools, never or almost never have the opportunity to do experiment in a school laboratory. Only about 5-6% of the population of students in Poland is constantly under the impact of this form of learning at the lessons of natural sciences (http://eduka.waw.pl/download/prospekty/indywidualizacja_mail.pdf).

Moreover, the report of the Ministry of National Education from 2010 draws attention to the very small number of the experiments done in frames of lessons, in spite of their recommendations in the core curriculum, as well as insufficient equipement in classrooms dedicated for teaching natural sciences at schools (http://www.men.gov. com /).

It should be emphasized that chemical experiments are a very important part of the lesson, and one of the most important methods of teaching. Experience, in addition to numerous other educational functions, plays a very important (and underappreciated) role - it contributes to the intelectual education of pupils [Nodzyńska, 2005].

On the other hand, microscope is one of the most important tools used in the teaching of the natural sciences. Its use in the classroom shapes not only manual skills of students, but most of all their intellectual abilities, harmoniously linking theoretical knowledge with practical work of the intellect with the work of their hands. Its use allows to provide students many experiences and to shape their creative attitudes toward science, nature, and to the natural environment.

The student, on his own, can see what is invisible to the unaided eye, which is described in the textbooks and compare the observed image with pictures placed therein.

Undoubtedly, the use of the microscope in presenting issues of natural sciences is extremely productive matter. The optical microscope can have wide range of applications in biology, such as observation of plankton or animal blood cells and bacteria as well. In chemistry classes for surface analysis of minerals and the crystalline changes. Scanning microscope can be used by the students to observe the surface structures of cell membranes, insect wings or pollens.

Color, texture, incredible microscopic image are some of the stimuli that act on the mind of the young man. Experience with microscope deepens knowledge, highlights it, and also contributes to a longer remembering of this knowledge by students. In addition, microscopic observations during the lessons of natural sciences enchance the condition of interest and attention. Sometimes it is said that this tool is a science, work and play, which evokes positive emotions among students [Gdaniec-Pietryka, Namieśnik & Zabiegała, 2008].

In this paper the use of an optical microscope during chemistry classes, when the students acquire knowledge on salts, is presented. Special attention is paid to the image of the structure of crystals formed in chemical reactions. With this option, students have the opportunity to see live forming crystals, instead of looking at presented in the form of photographs that appear in school textbooks. Moreover by preparing all substrates for the reactions students repeating the knowledge on the methods of preparation of various salts.

Application of the microscope in chemistry classes also allows to show students examples of electrochemical reactions. An important role of the teacher should be to provide knowledge on electrochemistry in an accessible, interesting and encouraging students to explore that issues. It should be emphasized that the core curriculum for lower high school does not provide explicitly

introducing issues of electrochemical reactions, however, corrosion of metals, the reactions of metals with acids or salts are present in the chemistry curriculum.

The microscope stimulates the student, encourages him to observe, draw conclusions and learn to understand the reactions occurring in the environment base on the knowledge of the microworld.

The experiments were done using Bresser MicroSet microscope. It gives the possibility to obtain the magnification from 40 to 1024x. Moreover, the microscop can be coupled with the computer and the image can be recorded and presented with a multimedial projector.



Fig. 1. Microscope, which was used by students to perform experiments. Model Bresser MicroSet 40 - 1024x.

The research

The main goal of the study was to determine whether the use of the microscope in the chemistry classroom would allow students of high school to better understand the changes taking place during the chemical experiment. In addition, the experiment will also determine the effectiveness of using the the microscope in chemistry teaching.

Hypothesis H0 of the study assumes that the use of the microscope in conducting experiments on the chemistry lesson allow students to better understanding its results.

The chemical reaction, due to the use of the microscope, will engage students through: their active participation in its use, unlimited opportunity to observe and perceive changes in the reaction process.

Moreover, it also assumes that the use of the microscope will increase the interest and motivation of students. Their active participation in lessons and the opportunity to engage in the experience carried out will help to increase interest in the subject discussed in the lesson.

The study was conducted using the technique of parallel groups. Pedagogical experiment was carried out on groups of pupils of IInd and IIIrd classes of lower high school. In the control groups the lessons were conducted with experiments performed using microscale technique (the technique has been already known to students). The experimental groups had the same experiments performed using a microscope connected to a computer and projector (it was a new experimental technique for students).

Chemical experiments are based on the script ,,Laboratory classes of general and analytical chemistry ' (Paśko, Sitko: 2007).





Fig. 3. Students performing the experiment.

After all the experiences and systematizing the knowledge students were tested. The test contained the same questions for both groups: control and experimental.

Task 1 (0 - 6p.)

Complete the following reaction equations:



Task 2 (0 - 6p.)

Fill in the missing fields in the table:

Name	Molecular formula	Structural formula of
lead(II) carbonate		
	BaCl ₂	
iron(II) phosphate		

The first task examined the ability of writting and balancing of chemical equations as well as the correctness of writing summary formulas of salts. In the second task students were asked to fill in gaps in the table with the salt's name its chemical formula and structural formula.

In order to verify the hypotheses the analysis of the results have been done.

Results and discussion



Fig. 4. Comparison of correct answers in the control group and the experimental (second class of lower secondary school).

Figure 4 (research on pupils of IInd class of lower secondary school) shows that the experimental group received better results in answering all the questions of the test. The differences are significant. When analyzing the responses to particular questions it can be stated that in the case of question 1 experimental group received better results by 10.97%. Meanwhile, in the case of the second question, this difference is larger and is up 25.92%.



Figure 5 Comparison of correct answers in the control group and the experimental (third class of lower secondary school).

Analyzing the chart (research on pupils of IIIrd class of lower secondary school) above also it can be seen that the total experimental group received better results than the control group. The graph shows that the differences are significant. For the first question, the control group received a worse score by as much as 12.5%. In the case of the second question is also underperformed by 12.5%.

For students more difficult was the first task, in which students have mistakenly written down formulas of salts, but also incorrectly balanced the reaction equations. Most likely this was due to ignorance of the valences. Students who performed the experiment with the use of the microscope and chemistry technique on a small scale, had fewer problems with answering this question.

Conclusions

The research in this paper clearly show that the use of the microscope in the chemistry classes becomes more favorable for the student in terms of speed and ease of learning. A student who use that research tool can quickly and safely conduct an experiment in frame of a teaching hour. The study confirmed that the use of microscope in the chemistry classes led to a better understanding of the particular issue and the changes, that take place during the performed experiment. In addition, it shows clearly that the microscope forces students to more active participation in chemistry lessons and increases their interest in the discussed topic. Furthermore, the results of the pedagogical experiment reveal that lessons with the use of microscope are taken with enthusiasm.

Microscope as a research tool allows students to notice the changes occurring during chemical reactions, which are not able to capture the by the unaided eye. It should be noted that the work with the microscope allows students to learn the proper handling of this tool, as well as the practical use of its features in chemical experiments.

Undoubtedly an experiment pointed pedagogical usefulness and positive contribution microscope in the process of acquisition of knowledge by students. Their motivation to learn and expand knowledge of the natural sciences, which is the chemistry has increased. Topics realised in the classroom has become more transparent, which affected the activity of the students in a discussion with the teacher. In addition, the ability to display microscopic images with a data projector on a screen during the lesson enabled active participation of all students in the performed experiment.

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Patrycja Pikuzińska, Paulina Pluta, Paweł Cieśla, Małgorzata Nodzyńska

Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

APPLICATION OF MICROWAVE OVEN IN CHEMISTRY TEACHING

Paulina Pluta, Małgorzata Nodzyńska, Paweł Cieśla

The teaching of the sciences, including chemistry is an important part of the learning process of children and youth. Thanks to the natural subjects, students learn to receive the reality with researcher's eye and familiarize with reactions, phenomena and processes taking place in the world around them. It is important that the taught contents are not just only words and are supported by active action. Methods, techniques used in the lessons of natural sciences should make the learning for students be both more attractive and easier. For this purpose, a laboratory method is commonly used utilizing chemical experiments as an essential part of the lesson. Such active participation of a student in the lesson stimulates the motivation and desire to explore knowledge. Chemical experiments affect not only the mental realm, but also emotional student. Execution of experiments by students allows you to create a problematic situation whereby students think creatively, communicate effectively and remember different information.

Since the first appearance of the mention of the possibility of using microwaves in organic synthesis (articles from 1986 by Richard Gedye'a, Frank Smith and others) over two thousand articles describing the use of microwaves have been written, including the synthesis of substances for medical purposes. Microwave assisted synthesis plays an important role due to the high efficiency and selectivity, easy separation, purification of the products and economy. Direct heating by microwaves greatly reduces the time for performing the chemical reaction, and also it is possible to decrease side reactions.

Microwave chemistry is based on the efficient heating of materials by the absorption of electromagnetic radiation of the microwave range by the molecule and increase its thermal energy caused by damping effect of the molecular vibrations. This phenomenon is dependent on the ability of the material (a solvent or reagent) for absorbing microwave energy and of transforming it into heat. These properties indicate, for example water molecule. During the interaction of microwaves an increase of product formation rate (sometimes changed) compared to experiments using a water bath is observed. It is now believed that in most cases the cause of the observed changes is purely thermal effect which is the result of the reaction at high temperatures, which can be rapidly achieved after irradiation of the polar material in the microwave field. Examples of studies available in the literature show that in many laboratories, chemical synthesis is carried out by microwave heating. Among the advantages of using a microwave to perform experiments are mentioned in addition to improved efficiency and a speed that the mechanism for monitoring the temperature and pressure in modern microwave ovens allows good control of the reaction parameters, which usually leads to more reproducible reaction conditions. On the other hand, the limitation to the reactions in a microwave oven may be the fact that not every compound can be used for this type of synthesis. For example, chloroform, carbon tetrachloride, or toluene should not be used for experiments in the microwave.

Microwave oven also found applications in a school lessons. Before the lesson the use of the oven was tested for safety work. The subject of experiments was different. Initially, the food was heated, and then appeared simple chemical experiments on physics or chemistry classes. Teachers of California schools have used the microwave for some time and believe that this method can be certainly a great show for students at every level of education and each student will be interested. Performed experiments related to both physical effects - glowing light bulb in a microwave, and chemical topics - chemical properties of soaps, fats and protein. In the Czech literature the procedures of experiments on using microwaves in chemistry classes, both in organic and inorganic chemistry (metal heating, aspirin synthesis, synthesis of soap, the synthesis of fluorescent dyes) can be found. [Šulcová & Nývltová 2004a; 2004b]

It was decided to examine whether the use of a microwave oven - appliance of common use - will affect the quality and the learning performance of students. Moreover, the aim of the study was also to check whether microwave oven - an unconventional tool for teaching - will make students interested in chemistry and teachers will be using experiments in education more frequent.

Research

Pedagogical experiment was conducted on a random sample of third grade of lower high school students.

Proposed the following hypotheses:

• The use of microwave oven in chemistry classes increases the interest in executed experiment and motivation of students to learn chemistry;

• Use the microwave oven for the esterification reaction and reaction of sugars and fats will allow for better understanding of these issues by the students;

• Use of the microwave makes it easy to carry out chemical experiments by the teacher in the classroom;

• Microwave will lower consumption of chemical reagents and laboratory glassware;

- Preparing classes with the use of microwaves is less time consuming;
- Classes with the use of microwave ovens are safer.

In order to verify hypotheses, several chemistry lessons have been performed, in which both the traditional method of performing chemical experiments, as well as the modified version - with use of microwave oven were used. Thematically lessons included material concerning organic chemistry, specifically esters and sugars - ie compounds with which the students come into contact in daily life. The classes were organized so that students could perform experiments individually. Prior to the classes appropriate lesson plans have been developed, which builds on the experiments described by Šulcová and Bohmová [Šulcová & Böhmová], as well as experiments described in school textbooks to study chemistry in lower high school. Also instructions for the student and the worksheet was prepared .

Before the lessons all reagents needed to carry out experiments have been prepared, and classroom was set to work in small groups. Preparing of each lesson took about two hours. Students performed experiments alone, according to the instructions. The teacher watched over the safety of students and supervised their work.

The task of the students was the synthesis of selected esters having at its disposal the following reagents, materials and devices:

ethanol, propan-2-ol, n-butanol, formic acid, ethanoic acid, propanoic acid, concentrated sulfuric acid (added by the teacher), the diluted solution of sulfuric acid, rack for tubes, wooden clamp to heating, heater, small beakers and microwave oven.



Fig. 1. A set of tubes with reagents for esterification.

It should be noted that in the esterification reaction carried out in a microwave oven as catalyst instead of concentrated sulfuric acid the diluted solution was used. At the following lesson, a test was performed that checked students' knowledge on esters.

Properties of sugars

On the first lesson, the teacher familiarised the students with a group of chemical compounds called sugars or carbohydrates, presenting their structure, chemical and physical properties, as well as the occurrence in nature and application. The second lesson was of a practical nature.

The task of the students was the examination of selected properties of sugars having at its disposal the following reagents, materials and devices:

The copper(II) sulfate(VI), nitrate(V) of silver, ammonia, sodium hydroxide pellets, sugars: glucose, fructose, sucrose, Benedict's reagent, starch, rack for tubes, wooden clamp to heating, heater, the beaker with water, funnel, microwave oven.



Fig. 2 - The first part of the reagents to a lesson on sugars.



Fig. 3 - The second part of the reagents to the lessons on sugars.

After completing the experiments by the students, the teacher summed up the lesson. At the next lesson, a test was performed that checked students' knowledge on sugars and anonymously completed questionnaire.



Fig. 4 - Microwave oven, which was used for performing experiments.

Results and discussion

As already mentioned, after the implementation of the experimental lessons two quizzes have been done in order to check assimilation of the knowledge by students. The selection of content that has been included in both quizzes, guided by the knowledge of the material realized in the previous lessons. Quizzes included questions concerning both writing equations of chemical reactions, naming, as well as design experiments. In addition, a short survey have been carried out.

Test on esters consisted of three open tasks. For the first task, students could receive a maximum of six points, for the second task could receive a maximum of five points and the third task could receive a maximum of three points. In total, it gave 14 points. In the first question the students task was to fill gaps in the esterification reaction equations with the missing formulae of substrates and products, and provide the names of the reactants. The results are shown in Figure 5.



Fig. 5. Summary of the results of the first task - quiz esters.

Students in most cases did not have problems with writing equations of estrification reaction, however, a problem with nomenclature of substrates and reaction products occured.

Students in most cases did not have problems with writing equations of estrification reaction, however, a problem with nomenclature of substrates and reaction products occured.

The second question in a test also checked the knowledge of nomenclature of alcohols, carboxylic acids and esters and also the structure of esters. The pupils were asked to write equation of estrification reaction with structural formulae and to give names of the reactants. In addition, the students' task was to select fragments of molecules which are disconnected, forming water. The results are shown in Figure 6.



Fig. 6. Summary of the results of the second task - quiz esters.

The presented figures 5 and 6 reveal that the theoretical material still needs to systematize and exercise.

Third task required that students demonstrate not only knowledge about the esters, but also the skills of designing chemical experiments. The pupils' task was to design experiment (description of experiment, drawing, observation) that allow to prepare ester with the specified name.



Fig. 7. Summary of the results of the third task - quiz esters.

As it can be seen in the figure 7 only five students did not answer that question. Most of students did not have problems with this task. Students mainly lost points on the description of the experiment, usually forgetting the catalyst, while as many as twelve people finished the job in a flawless manner.

Quiz on sugars consisted of three open tasks. For the first task, students could receive up to four points for the second task could receive a maximum of two points and the third task could receive up to five points. In total, gave it 11 points.

The first task was: "Write down the molecular formula and draw the structures of glucose and fructose." All students were able to write sumarised formulae of both sugars, and no student was able to draw structural formulas of fructose and glucose. The second task was to discuss the physical properties of glucose. This task revealed not to be difficult for students.

Third task, as in the case of esters, referred to the experimental lessons and was "Suggest experience in which you can show the presence of glucose in the sample." This task made most difficulties to students. Students most often correctly wrote down the purpose of experiences, observations and conclusions to the experience. The problem appeared when the substrates were going to be named - the students instead of writing that they add to the test tube a test sample they wrote that they add glucose. After that they wrote down that there is glucose in the sample. The similar situation was observed when students were drawing picture describing the experiment.



Fig. 8. Summary of the results of the third task - quiz sugars.

Results of the questionnaire

The first question in this survey was to check whether the students find experiments with microwave more interesting than the traditional method of doing experiments - on the tables, in test tubes heated by flame. Summary of students' responses are presented in the following graph:





The results show that 19 students believed that the experience of using microwaves are more interesting than experiments conducted using the traditional method, 7 students are of the opposite opinion, and 9 students have no opinion on the subject. It can therefore be concluded that the surveyed students only slightly better assess the attractiveness of experiments performed with microwave than the traditional method

The second question in a questionnaire asked if the description of the experiment using the microwave was understandable. Below is a summary chart of students' responses:



Was the description of the experiment using the microwave understandable?

Fig. 10. Summary of the responses of pupils on the second question In the questionnaire.

Fig. 9. Summary of the responses of pupils on the first question In the questionnaire.

The obtained data show that for the majority of students description of the experiment using the microwave was clear and understandable. 29 students answered affirmatively to the question, while the remaining 6 answered in the negative.

Another question in the questionnaire was whether the use of microwave was helpful during the development of knowledge on organic compounds such as esters or sugars.







The results show that 20 students believed that the use of microwave was helpful at the time of acquiring knowledge of organic chemistry, while 15 students believed the opposite. It can therefore be seen a slight advantage of students who ppreciate the use of microwaves in class.

Questions: fourth and fifth were open. Both required students to comment on the positive and negative features of performing experiments in the microwave oven. After a thorough analysis of the results it can be said that dominated several types of student responses. They are summarized in the following table:

Pozitive	Negative
-faster execution time of experiment -safer -more interesting -enrichment of a lesson	 not clear mechanism of the reaction; the beaker is not seen and thus the effects of the reaction are not visible fast heating of glassware problems with visibility of the experiment in the classroom. one microwave oven for whole, big group of pupils; high consumption of power.

Table 1. Students' responses to questions: fourth and fifth of the questionnaire. Features of performing experiments in microwave oven.

The last question in the survey concerned the overall assessment of the work with microwave at chemistry classes in a scale from 1 to 5.

The results are presented below, at figure 12.



How would you generally assess the use of microwave

Fig. 12. Results of the general assessment of the method.

Most students rated the work with microwave well (score 4) - (12 students) or medium (score 3) - (11 students). In contrast, 7 students rated the use of microwaves in the classroom as very good (score 5). 5 people rated this method as "good" (score 2). Among the respondents, there was not any student who said that the use of microwave chemistry lesson is wrong. The average assessment of the method is 3.6 which is not too high evaluation.

Discussion and Conclusions

Looking at the results of the survey it can be seen that students are interested in a lesson on which to perform experiments a microwave oven have been used. However, this is not a very intense interest. Students like the fact that the lesson uses devices of everyday use and they are curious about the effects of the reaction. However, it can be seen that the general interest in using microwaves to perform chemical experiments is only temporary, because this is something new custom device used in the experiments. Despite the interest the vast majority of students, as many as 23 assessed the work of the microwave just as good or average. Students demonstrate both the advantages of this method and its disadvantages, thus their opinions are divided.

People positively expressing themselves on the subject, relied on their own feelings and emotions associated with the lesson. There were sentences "lesson is interesting", "lesson is varied." There were also arguing associated with the issue of safety in the classroom. Students in the majority felt that it is safer to carry out reactions in the microwave, because there is no need to worry that the contents of the beaker in which the experiment is carried out will, for example, shoot us in the face. A very important positive feature of performing experiments in the microwave students recognize shorter time of performing such experiments. The students themselves have had the opportunity to compare the execution time of the experiment using the traditional method, and the method of using a microwave oven.

Students also discussed whether the reaction mechanism in microwave oven experiments is exactly the same as in the case of traditionally performed experiments? This question encouraged students to mention the negative features of using microwave in chemistry teaching. Pupils were disapointed with a fact that through thick and tinted glass in doors of microwave oven they couldn't not see the beaker in which the reaction was performed, and thus the students could not see the end of the point at which, for example, the mixture changes the color or something precipitates. In addition, students complained about the visibility and availability of the microwave for the whole group.

The lessons in which students on their own perform experiments using the microwave oven requires a greater number of these devices, because the accumulation of too many people around one device introduces chaos. It is interesting that the students also mentioned that this method requires higher power consumption, what may indicate a good knowledge and care about sustainable development - including the energy saving and environmental activities.

Experiments performed in a microwave can be a major element of the lesson. They are easy to make, conducted on a small scale are safe for execution, execution time is shorter compared to other methods of conducting the experiment, the ease of use of the apparatus. Unfortunately, in the case of the experiment in a microwave oven is limited visibility, which makes observations for pupils difficult. We are also not able to predict the side effects that can interfere with the observed image, and also reaction mechanism can remain incomprehensible. For example, the fact that the esterification is carried out in a microwave oven, instead of concentrated sulfuric acid is used in its diluted solution may suggest a different mechanism of reaction taking place. Students also said that the use of microwave chemistry lesson did not help them in gaining knowledge of the esters and sugars, which confirms in the results of the conducted tests.

Checking students' ability to plan and design experiments, the vast majority of them received more than half of the possible points for the solution of the problem. All students were able to write proper observations. This may indicate a pozitive effect using the experimental methods for chemistry classes. Students, thanks to the individual performance of the experiment were able to move gained in this way, knowledge and skills onto a paper. Students had the flexibility in choosing the method of receiving ester, however, all of them chose the traditional method. None of the pupils writing quiz has not used there the possibility of using microwaves to receive these esters. Have students forgotten that they performed such experiments only lesson before? Did they recognize that this method is not effective enough? One can guess that the students are so much accustomed to performing chemical experiments using the traditional method - using burners and test tubes, so they did not take into consideration at all the other possibilities.

Microwave, briefly entered, did not attract their attention so much that they coud remember that it is not only element which enrich lesson, but also very good and fast method for the preparation of esters.

Similarly, when planning an experiment for sugars, students were able to perfectly make a note of the observations to the experience they also had no problems with definition of aims of the experiment and the description of laboratory procedure. This shows again that the performance of chemical experiment works on the motivation of students to acquire knowledge and skills in the subject. The results confirm the important functions that chemical experiments play in the education of students. Unfortunately, they also repeated earlier thoughts on the use of microwave in chemistry classes - this does not have a direct impact on the learning process. Furthermore confirm the assertion made by M. Łobocki, who noted some shortcomings in the use of the rotation method. Briefly entered the independent variable - microwave oven - increases students' interest in the lesson and their commitment to work in class. But in the long term, it brings no such effects as traditional method. Thus two hypotheses, which were raised in frames the pedagogical experiment: "the use of microwave oven for the esterification reaction and reactions of sugars will allow for better understanding of these issues by the students" and "the use of microwave in chemistry classes increases the motivation to learn chemistry" were rejected.

Another hypothesis which was stated assumed that the use of microwave makes it easy to carry out chemical experiments by the teacher in the classroom. Based on observations which were made during the studies cannot confirm the validity of this hypothesis. On the one hand actually use of the microwave has many advantages, but also has the disadvantages such as the difficulty of observation, especially when there is only one microwave and the class has more than 30 people. Experiments carried out using a single microwave oven are for demonstration purposes only, in which the states before the reaction and after the reaction are observed.

Studies confirmed the validity of the next two hypotheses, one of which says that the use of microwave at chemistry classes increased the interest in a performed experiment, and the next says that the classes with the use of microwave ovens are safer than the traditional method without using the micriwave oven. Larger safety of students is ensured by isolating the student from direct contact with the reaction system, and thanks to the use of safer reagents.

The hypothesis that the use of the microwave oven allows for lower consumption of chemical reagents and laboratory glassware also haven't confirmed. On the one hand, the use of microwaves reduces consumption of concentrated reagents, which is a huge plus, but on the other hand, larger volumes of reagents are required. For example, the Tollens test performed in a microwave needs four times more volume of sugar sample. The use of laboratory glass, however, is lower than in the traditional method because it may be limited to the use of several beakers and microwave, as opposed to the traditional method where the performance of the same experiences need much more glass and equipment. Preparation of classes using the microwave is also less time consuming, as it usually requires the use of smaller amounts of glass and equipment than the same experiment performed using the traditional method.

Introduction of the microwave oven to perform various experiments in the classes of natural sciences, including chemistry, should be investigated more thoroughly. Moreover, reactions occurring during the heating of substances in a microwave oven should also be carefully verified. Polish school still requires many changes and they will certainly take place in the near future, so it is not worth to removing the investigated method at the begining, however it requires both the educational as well as technical tuning. In near future it might be one of a great alternative for teachers to perform chemical experiments in school practice.

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Patrycja Pikuzińska, Paulina Pluta, Paweł Cieśla, Małgorzata Nodzyńska

Pedagogical University of Cracow, PL

malgorzata.nodzynska@gmail.com

CONDESATION REACTIONS OFBENZAALDEHYDE AS MICROWAVE ASSISTED SOLVENT FREE EXPERIMENT

Kateřina Zemanová, Jiří Havlíček, Walemar Tejchman, Karel Kolář

Introduction

Condensation reactions of carbonyl compounds with amines, hydrazines, hydroxylamine and semicarbazide are well known in chemistry education. The products of these reactions are imines, hydrazones, oximes, semicarbazones, etc. By-product of the reaction is water. The reactions proceedvia addition-elimination mechanism. The first step is a nucleophilic addition. Amine, or other compound, whose molecule has a nucleophilic character, attacks the carbon atom of the carbonyl group, the addition will be associated with the disappearance of the double bond between carbon and oxygen. In the sekond step, from the adduct is subsequently eliminate the molecule of water. The product contain the double bond between carbon and nitrogen.

The product of reaction benzaldehyde with aniline is benzyliden aniline, as shown in the following equation.

Benzaldehyde phenylhydrazone is the product of reaction benzaldehyde with phenylhydrazine.

Benzaldehyde oxime is the product of reaction benzaldehyde with hydroxylamine.

$$\longrightarrow$$
 0 + H₂N OH \longrightarrow \bigwedge N OH + H₂O

In this case it must be present in the reaction mixture alkali (sodium carbonate, sodium acetate), because hydroxylamine is in the form of salt (e.g. hydrochloride).

The condensation reactions of carbonyl compounds are often incorporated to laboratory exercises in organic chemistry at the university and high schools. There are several reasons, this is easily feasible reactions with minimal equipment of the laboratory technique, the time of reaction is relatively short, the reacton products can be easily isolated. These reactions we still tried to realized in line with contemporary trends as reaction without solvent in the presence of microwaves in order to further simplify the conditions for their realization. Own reactions implement the conditions of microwave heating (polarity of molecules, etc.)

Experimental

The reaction was carried out in a porcelain crucible in a commercial microwave oven (2450 MHz, 700 W). Composition of the reaction mixture was controlled by TLC (thin layer: silica gel with luminescent indicator, eluent: hexane – ethyl- acetate (8:2), detection: UV lamp - λ = 254 nm). R_F of starting material are the following : benzaldehyde - R_F = 0.55, aniline - R_F = 0.21, phenylhydrazine - R_F = 0.07. R_F of products: benzylidene aniline - RF = 0.66, benzaldehyde phenylhydrazone - R_F = 0.34, benzaldehyde oxime - R_F = 0.37. In this experiment was investigated: the effect of the ratio of reactants, time of heating and microwave power on the reaction course.

Equipment, chemicals

benzaldehyde, aniline, phenylhydrazine, hydrochlorid hydroxylamine benzylidene aniline, benzaldehyde phenylhydrazone, benzaldehyde oxime, hexane, ethyl acetate, sodium bicarbonate, sodium acetate trihydrate, a commercial microwave oven (2450 MHz, 700 W), the porcelain crucible 10 cm³, watch glass, chromatographic chamber with the cover glass, a thin layer (silica gel) with a luminescent indicator ($\lambda = 254$ nm), UV lamp for the detection of chromatograms, test tubes, capillaries.

Procedure

1) Into porcelain crucible (10 cm³) weigh 0.42 g of benzaldehyde and add 0.37 g of aniline.

2) The crucible cover with a watch glass and place in center of a rotating plate microwave oven.

3) Heat the reaction mixture at half the microwave power for 1 min.

4) After heating the crucible with the reaction mixture, place for about 5 min. in the ice-box.

5) From the reaction mixture in a crucible to remove a small sample (spatula tip) into the test tube, and dissolve it in about 3 cm³ of the mixture hexane: ethyl acetate (8:2).

6) In the second test tube, dissolve a small amount (one drop) benzaldehyde (standard) in about 3 cm³ of the mixture hexane: ethyl acetate (8:2), in the third tube, dissolve a small amount (one drop) aniline as a standard in about 3 cm³ of the mixture hexane: ethyl acetate (8:2). The last standard (benzilidene aniline) dissolve under the same conditions in a small amount (spatula tip) in the fourth test tube.

7) The sample of the reaction mixture together with the samples of standard apply on a thin layer of silica gel with luminescent indicator and place in the chromatographic chamber with eluent. (hexane: ethyl acetate - 8:2).

8) Chromatogram take out from chromatographic chamber and detect under the UV lamp, the starting materials and the reaction product formed on a thin layer of dark spots, in the reaction mixture identify benzylidene aniline as the main product, presence of by-products and unreacted benzaldehyde and aniline.

9) Experiment repeat for different heating times, different ratios of reactants and different microwave power, do the comparison of results and subsequent evaluation of the experiment.

10) Experiment repeat with phenylhydrazine and hydroxylamine hydrochloride.

In the first case, weigh of 0.11 g of benzaldehyde and 0.11 g of phenylhydrazine. In the latter case, weigh 0.07 g of benzaldehyde and 0.07 g of hydroxylamine hydrochloride. To this mixture add 0.07 g of sodium acetate trihydrate or 0.09 g of sodium bicarbonate, and add to the mixture 0.30 g of water.

In this experiments was studying the influence reactants ratio, time of heating, microwave power on the reaction course.

Results and discussion

Results of optimization the conditions in the case the reaction of benzaldehyde with aniline showed, that the reaction proceeds satisfactorily, when using the reactants in the ratio 1:1, microwave power is set to the medium level and time of heating is 1 min. Longer heating time is not required. The porcelain crucible was placed in the center of the rotary plate. Very good results were achieved also with the use of the lowest microwave power of the oven. In detail was studied reactant ratio benzaldehyde: aniline (2:1, 1:2). It turned out, that the change ratio of the reactants is not substantially for the reaction course.

The reaction of benzaldehyde with phenylhydrazine was carried out in the equimolar ratio of reactants. The influence of the time of heating on the reaction mixture was studied at 1 min. 2 min. and 3 min. The influence of microwave power was also studied. It has been shown that the minimum microwave power is not sufficient and it is necessary to adjust the oven at medium microwave power. The porcelain crucible was placed in the center of the rotary plate. The optimal result was achieved when using the reactants in the ratio 1:1, medium microwave power, the time of heating the reaction mixture for 2 min. and placing a porcelain crucible into the center of the rotary plate.

In details were also examined the reaction of benzaldehyde with hydroxylamine. Because was used hydroxylamine hydrochloride, it was necessary to perform the reaction in the presence substances that neutralize hydrogen chloride. These substances were sodium acetate and sodium bicarbonate. In the reaction has been used predominantly sodium acetate trihydrate. Other variables were time of heating (1 min., 3 min.) and microwave power (minimum power and mean power). Optimal conditions in this case, the reactant ratio of 1:1, time of heating 1 min. and medium microwave power. The crucible was placed in the center of the rotary plate of the oven.

Conclusions

The condensation reactions of aldehydes and ketones are often theme of laboratory exercises in organic chemistry at the university and high schools, because that are easily realized reactions. In this case, the experiment perform as reaction without solvent in the presence of microwaves. Under this conditions the time of reaction is relatively short, the consumption of chemicals is minimal, the reaction products can be easily isolated etc. The new form of experiments, which correspond with Green chemistry principles, was implemented to organic laboratory practice.

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Kateřina Zemanová¹, Jiří Havlíček², Walemar Tejchman³, Karel Kolář¹

¹ - Faculty of Education, University of Hradec Králové , Hradec Králové , CZ

² - Faculty of Science, University of Hradec Králové , Hradec Králové , CZ

³ - Pedagogical University of Cracow, PL

karel.kolar@uhk.cz

THIN LAYER CHROMATOGRAPHY OF SELECTED AZO COMPOUNDS IN CHEMISTRY EDUCATION

Jakub Vitvar, Antonín Lyčka, Karel Kolář

Introduction

Chromatographic properties of a compounds depend also on their structure. The influence of the structure on the chromatrographic properties can be described very good, if the compounds have the simple structure. In this case, the azo compounds were selected for this study. We solved four problems:

- the position of phenylazo group in the azo compounds and the chromatographic properties,

- para - substitution of phenylazo group and the chromatographic properties of azo compounds,

- the influence of nitro group in para – position phenylazo compunds on the chromatographic properties azo compounds,

- the influence of hydroxy group and amino group on the chromatographic properties azo compounds.

Results of the experiments can be used in teaching of chemistry on the university or high school.

Experimental

Chromatography was realized in traditional chromatographic chambers on the thin layer of silica gel with toluene as eluent. Because all compouds are coloured, visualization is not necessary.

Results and discussion

The first experimental exercise is oriented on the comparison the RF of two compounds (2-phenylazo -1- naphtol (Substance A), 4-phenylazo – 1-naphtol (Substance B)).

Value RF of the first compound is greater, than value RF of the second compound. The explanation of this phenomena is the intramolecular hydrogen bond in the first compound.



Substance A (RF=0,84)

Substance B (RF=0,60)

1. chromatogram

In the second exercise are compared RF values of 4-phenylazo -1- naphtol (Substance B) and 4-(1-naphtylazo-1- naphtol (Substance C)). Value RF of the second compound is greater than value RF of the first compound. In this case, the eluent most strongly interact with naphtylazo group than phenylazo group.



Substance B (RF=0,60)

Substance C (RF=0,65)

2. chromatogram

In the third exercise, RF value of 4-fenylazo -1-naphtylamine (Substance D) is greater than RF value of 4-(4-nitrofenylazo) -1-naphtylamine (Substance E). Second compound can be strongly interact with sorbent. The experimental results of the exercise can be explained as influnce of nitro group at second compound



Substance D (RF=0,55)

Substance E (RF=0,30)

3. chromatogram

The fourth experimental exercise are oriented on the disscusion of RF values of the 4 – fenylazo -1-napthol (Substance B) and 4-fenylazo -1-napthylamine (Substance D). RF value of the second compound are smaller than RF value of the first compound. The experimental results of the exercise can be explane as strong hydrogen bond between OH group of silica gel and NH2 group of azo compound.



Substance B (RF=0,60)







4. chromatogram

Conclusions

Experimental exercises can be show the posibility of chromatographic properties interpretation on the basis small interactions, for example hydrogen bond. It may be use for the demonstration of small interactions in the chemistry education on the university or high school.

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Jakub Vitvar¹, Antonín Lyčka^{1, 2}, Karel Kolář¹

¹ - Faculty of Science, University of Hradec Králové, Hradec Králové, Czech Republic

² - Research Institute of Organic Synthesis, Pardubice, Czech Republic

SIMPLE EXPERIMENTAL MODELS OF ANTIDOTE ACTION IN THE CHEMISTRY TEACHING ON HIGH SCHOOL

Jindřich Zdražil, Karel Myška, Karel Kolář

Introduction

The mechanism of the action of toxic or antidotal substances on the human organism can be modeled etirely through a simple form of precipitating or complex form reactions. Antidotal agents may act by different mechanisms, usually by converting of toxic substances to nontoxic substances. Mostly it is the conversion of toxic water-soluble substance to water-insoluble substance or water-soluble, but non-toxic substance (different type of complexes).

As the antidote for water-soluble compounds of barium are used sodium sulphate. The water-soluble compounds of barium react with sodium sulphate. Product of the reaction is water-insoluble barium sulphate (white precipitate). The reaction is realized in a tube with 3cm³ of 1% barium chloride and few drops of 3% sodium sulphate. Product of the reaction – barium sulphate is the white precipitate, which is non-toxic, because it is water-insoluble substance.

 $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Simiraly, soluble copper compounds may equally be precipitated from solution by the reaction with sodium ferrocyanide (for school experiment can be use potassium salt). Product of reaction is cupric ferrocyanide (brown precipitate). The experiment was performed in the same manner as above. A few drops of 3% sodium ferrocyanide is added to 3cm³ 1% cupric sulphate.

 $2Cu^{2+} + [Fe(CN)_{6}]^{4-} \rightarrow Cu_{2}[Fe(CN)_{6}]$

Fluoride or oxalate poisonings require calcium chloride or calcium gluconate as the antidote. Completely analogous conditions, as in the two previous experiments, the water-insoluble salts are formed (calcium fluoride, calcium oxalate).

$$2F^{-} + Ca^{2+} \rightarrow CaF_{2}$$

$$(COO^{-})_{2} + Ca^{2+} \rightarrow (COO)_{2}Ca$$

Very common and dangerous are water-soluble compounds of lead poisoning. The organic compounds, sontaining –SH groups used as antidotes. The special synthetic compounds, for example dimercaprol, also known as BAL (British Anti Lewisite), has been successfully used after intoxication of human organism by warfare agent Lewisite. Another substances are sodium-dimercaptopropansulfonat (DMPS) and dimercaptosuccinic acid (DMSA).



The product of such reactions are water-insoluble products, in which ions of heavy metal are bonded on the atoms of sulphur in the –SH groups.





Ions of metals can also bind to the soluble complexes with derivatives of the ethylenediaminetetraacetic acid (EDTA).



EDTA

As the antidote is used calcium-disodium salt of EDTA, which can be substitute for educational purposes disodium salt of EDTA (Complexone III).



Fig. 02. The complex of lead ions with EDTA.

The antidotal effect in the case of heavy metals poisoning due to the presence of –SH group in molecule show cysteine. The proteins, which contain the cysteine, have the same properties. Such proteins are present, for example, in milk or egg white. The heavy metals cause denaturation of the proteins. They form water-insoluble products. We can realized two simple experiments. To two tube is given 3cm³ of lead nitrate. Into the first tube add several drops of 3% cysteine and to the second tube a few drops of saturated solution of ovalbumine. In both cases, the white precipitace of non-toxic complexes are the products. The protein in the reaction with heavy metal, on the other hand, can serve as the model of the heavy metal toxic effect on human organism. Reaction formed the water-insoluble product (white precipitate), which simulates the toxic effect of lead salts (denaturation of proteins). If we add a few drops 5% disodium salt of EDTA (Complexone III) to 3cm³ of 1% lead nitrate and then a few drops of saturated solution of ovalbumine, no water-insoluble product form. Lead ions are already bound to the water-soluble complex with disodium salt of EDTA.

Heavy metal salts for demonstration experiments were chosen lead nitrate and cadmium nitrate. Mercuric nitrate is not suitable for student experiment (high toxicity). Reaction of 5% lead nitrate with saturated solution of substances containing –SH group (ovalbumine, cysteine), produced of white precipitate (water-insoluble complex). The salts other heavy metals (Cd²⁺, Cu²⁺, Ag⁺) form the intense or weak turbidity.

The rsults of experiments also shows a substantial number of simple experiments can be easily performed in chemistry teaching at the high school or university. The experiments are the simple models of processes in the human organism.

Experimental part

The issue was tested in teaching of chemistry at the high school in Czech Republic and Germany. One half of the students pass the traditional interpretation of thematic unit. The other half of students pass the experimental part after theoretical lessons. Teaching experiments are located in the following list.

Teaching experiments

1) Effect of sodium sulphate as antidote after water-soluble barium salts poisoning

To a tube with 3 cm³ 3% barium chloride add a few drops of 5% sodium sulphate. A white precipitate of barium sulphate is the non-toxic product of reaction.

2) Effect of sodium ferrocyanide as antidote after water-soluble cupric salts poisoning

To a tube with 3 cm³ 3% cupric sulphate add a few drops of 5% sodium ferrocyanide. Product of reaction is non-toxic brown precipitate (cupric ferrocyanide).

3) Effects of calcium salts as antidote after fluoride or oxalic acid poisoning

To a tube with 3 cm³ 3% sodium fluoride add a few drops of 3% calcium chloride. Product of reaction is non-toxic white precipitate (calcium fluoride).

To a tube with 3 cm³ 3% oxalic acid add a few drops of 3% calcium chloride. Product of reaction is non-toxic white precipitate (calcium oxalate).

4) Toxic effects of water soluble lead salts on the protein albumine

To a tube with 3 cm³ 1% lead nitrate add a few drops of saturated solution of ovalbumine. White precipitate is the proof of protein denaturation.

5) Effect of Complexone III as antidote after the interaction of albumine with water-soluble lead salts

To a tube with 3 cm³ 1% lead nitrate add a few drops Complexone III. To the mixture add a few drops saturated solution of ovalbumine. The white precipitate is not product of the reaction. Lead ions form with EDTA stable water-soluble chelate ccomlex.

Questionnaire inquiry - items

1) What are the antidotes? (1 point)

2) What may be a general principle of removing the toxic substance? (2 points)

3) Give the specific example of general principle of antidote effect. (2 points)

4) Which antidote can be used to remove water-soluble barium compounds from the human organism? (1 point)

5) Describe the reaction of antidote with toxic toxic substance by equation. What is the principle of detoxication the poison? (2 points)

6) Which antidote can be used to remove water-soluble cupric compounds from human organism? Describe of antidote reaction with the toxic substance by equation. What is the principle of the toxic substances removal? (3 points)

7) What antidotes we can use in the case of the fluoride or oxalate poisoning? Describe the equations of reactions between toxic compounds and antidotes and principles of antidote effect. (3 points)

8) After poisoning by the water-soluble heavy metals compounds can be used as antidote the substances containing the particular type of functional groups in the molecule. Please, provide a characteristic group, the examples of this compounds and the principles their antidote effect. (2 points)

The maximum - score: 16 points (average of 2 points per exercise).

Results and Discussion

Questionnaire inquiry was realized independently on the two school (Friedrich Schiller High School Pirna, Germany, High School Přelouč, Czech Republic). Pedagogical research had to be modified with regard to conditions within the Czech-German project, which takes place at the schools. Within the framework of the project of Czech students are educated from seven class. They complete of the german students class. In the first stage of high school (Grundstufe/ Sekundarsufe I) Czech students have some subjects in the Czech language. In the second stage of high school (Oberstufe/Sekundarstufe II) classes in fact disappear and students are divided into courses according to the specification. The study is now only in German. At this level only taught by German teachers, in addition to Czech language teaching. Chemistry teaching begins to Czech students in eighth class in Czech language. The peculiarity of these groups are personal relationships, because students spend togethert almost all the time, creating various social groups, which have different charakteristic than in the case of the usual classes.

There were thus only three groups (8.-10. classes) on the small number of students (10-15). In the other case, the research was realized under conditions, quite common on the high schoo level (eight classes with the average 26,4 students per class).

The students were divided into two efficiency commensurable groups. Accidental selection was determined, which these two groups will be complemented the research by selected experiments. Research was carried out approximately in the middle of the second session.

Before starting of the research were formulated three hypotheses:

The research will be successful in case of the students were included in the teaching an experiment, than students who no experiment in the teaching included.

The results of research will correspond with the age of the students and thus their knowledge and experience.

The results of research will be in relation to the characteristics of each class.

As already discussed, verify the effect of the inclusion the model experiment to teaching on understanding and mastering of the difficult subject matter was based on the comparison of two parallel groups of students. One of these two groups had expanded interpretation of the experimental part, which folloved immediately after the teoretical part. Subsequently, after one week, it will be verify by the using exploratory methods (questionnaire) to ascertain the extent to which students have mastered the subject matter and the influence of selected experiments. For the relevance of the results it was necessary to divide the students into groups so that these two groups were comparable in the performance.

Thematic unit Antidotes was the subject of pedagogical research from a several reasons. The models of antidote effect are the simple precipitation or complexation reactions. The reactions can be performed as microscale experiment in the tubes with a minimal laboratory equipment. In terms of the structure of substances or biochemical changes that these models represent, the models can be used for elementary school and high school. For theoretical part of the course was compiled the list of toxic substances and their antidotes. The list can be implemented into the chemistry teaching, for example, as part of chapter Safety in Chemical Laboratory. At the university is thema Antidotes implemented to subject matter of Toxicology. In this case, this chapter has been prepared as the discussion of toxic substances and remove them from the human organism. Of course, it was necessary to prepare the special text. The manual entitled Poisons and Antidotes was intended as the informational resource for teachers.

Subsequently, the gustionnaire survey examined whether the implementation of relevant experiments had the positive effect on the learning. The students solved the test after one week from realization of the experiments.

Evaluation of questionnaire.

Pedagogical research was attended by 228 students from 11 classes, which amounts to the average of 20,7 student per class. The girls were 134 (average 12,2 girls per class) and 94 boys (average 8,5 boys per class). Each student could be obtain maximum 16 points (100%).



Procentuální úspěšnost žáků v testu

Fig. 03. Achievment of students in the test solving in each classes (%).

Conclusion

The results of research indicate the positive effect of the teaching experiment on the successful solving of questionnaire items. In all classes, students were performing the experiment more successful than those who did not attend the experiment. At the same time various hypotheses were confirmed:

Students performing experiment were successful.

Students of higher classses were more successful.

Students from classes with favorable general assessment were successful.

The problems of toxic effects of chemical substances on the human organism, students enjoyed considerable attention. The interest of the students in the issue of toxic substances and antidotes can therefore be successfully developed with the help of the simple experiments in teaching of chemistry and other science subjects.

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Jindřich Zdražil¹, Karel Myška², Karel Kolář³

¹ - Friedrich Schiller High School Pirna, Geramany

² - Institute of Social Work University of Hradec Králové, Czech Republic

³ - Faculty of Natural Science, University of Hradec Králové, Czech Republic

karel.kolar@uhk.cz

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