HOUSEHOLD CHEMICAL EXPERIMENT IN THE DISTANCE LEARNING

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ABSTRACT

A case study on several distance learning activities including household chemical experiments is presented. The case includes school curriculum course for 8th grade (14 y.o.); two distance learning courses for 8-11 y.o. students; two courses supporting school curriculum for 8th grade. The framework of chemical experiments within the distance learning, the sources of material supply, synchronous and asynchronous modes of conducting experiments are described. *[African Journal of Chemical Education—AJCE 13(2), June 2023]*

INTRODUCTION

Distant learning has been drastically developing since the beginning of the COVID pandemic. However, it is older than the pandemic and even older than computers. For example, in 1964 the Moscow State University organized The All-Union Distance Learning Mathematical School. The secondary school students got textbooks and tasks, sent the solutions and received feedback – everything by snail mail. In some years more than ten thousand students studied there. In 1989 the "Distance Learning School of a Young Chemist" was organized – still using a snail mail and with no experiment.

At any rate the main demanders of the distant learning outside pandemic are:

- the students from the remote places with no good schools;
- expats – the students who live outside their country of origin and prefer to get education on their native language;
- the homeschoolers;
- students from big cities who don't want to waste their time for the traffic.

Herein we are going to share our experience in organization of hands-on chemical experiment within the distance learning chemistry courses (Table 1).

Table 1: The distance courses that were conducted

Name	Age	Number of sessions	Mode	Materials
Materials around us	7-10	4	Synchronous	Household (countryside)
Introducing chemistry	11-13	3x4	Both	Household + burner
Substances around us	11-13	12	Both	Household + burner + “Young Chemist”
Supporting school chemistry	14-15	20	Synchronous	Household + burner + “Young Chemist”
Chemistry for 8th grade	14-15	50	Asynchronous	Household + special kit (in progress)

In our country there are several types of the audience for the distance learning course. Surprisingly the largest audience is the children of 8-13 y.o. despite there is no chemistry in school curriculum for this age. We elaborated face-to-face laboratory activity for this audience [1] but after the beginning of COVID and due to demands of people from outside our city we transferred it into the distant course.

The smaller audience is the students of 8-9th grade (14-15 y.o.). Some of them study in a distant mode totally and don’t attend school. The others attend schools but claim experimental support for the regular school course because there is no experiment in the majority of the schools.

There are also a small number of the students, who needs distant learning courses to prepare for the State Exam, but there is a strong competition between courses for this audience and we didn’t work with it.

There are several possible solutions on incorporation of chemical experiment in the distance chemistry courses [2-3]:

- face-to-face experiments;
- household experiments (“kitchen” or using home study lab kits);
- remote control experiments;
- self-guided field trips;
- virtual labs;
- videotaped experiments.

We did not employ remote control experiments, when the glassware and reactants are somewhere, and the student manages them via Internet. It requires sophisticated but manageable equipment. Thus, it can be used for a limited number of complicated experiments such as preparation of a plastic foam [4]. However, our audience requires greater number of simple experiments. We also don’t have facilities to arrange the necessary equipment.

We also did not employ field trips – it is much more time consumable than household experiments.

We do use videotaped experiments within the school curriculum course if they can not be conducted at home (for example, reaction of sodium with water). However, there is nothing to discuss about the videotaped experiments.

We also use virtual labs within the school curriculum course just to fulfill the formal requirements.

Face-to-face experiments are also used in supporting of the school curriculum course. Students attend the lab for one day or for several days and conduct all the experiments on the topics they had been studying for several weeks or even months. However not so many students that attend the school curriculum course perform face-to-face experiments. The first reason is the small capacity of the laboratory. The second reason is the difficulty to get to the lab from the places outside our city. Moreover, the face-to-face experiments for distance learning have no difference with experiments for face-to-face learning.

The most interesting and most challenging is the household experiment and we will discuss this type in details. Many teachers are afraid of household experiments believing that they can be performed only at the laboratory. However, it is wrong. Many "kitchen" experiments basing on household goods are described (and were described before the computer era [5-6]. There are single experiments [7-8], sets of experiments [9], courses [10-11]. The experiments can be quite complicated, for example using smartphones as spectrometers [12]. The safety issues also prevent teachers from organizing household experiments, but these issues can be resolved.

THE FRAMEWORK FOR THE EXPERIMENTS

There is a mutual consent that experiments are essential for chemistry teaching that is confirmed by numerous reviews [13-16] For 8-13 y.o. students we arranged the experiment as a basis to developing observational and procedural skills and accumulating experience that would serve as groundwork for further studying chemistry [1]. In general, we are trying to develop “the sense of substance” as an ability to operate with substances errorless without explicit instructions. For 14+ y.o. students we used experiment as a basis for introduction of theories and concepts and as a tool of falsification them according to Karl Popper that fully presents the scientific method [17-18].

SOURSE OF THE MATERIALS

Now there are many chemicals around us – so many, that a simple chemical laboratory can be based just on household ones. Here is a list of chemicals, available in our country. The list is country-specific (for example, alcohol solution of iodine is unavailable in the majority of European and Muslim countries. On the contrary, sodium hydroxide is unavailable in our country but is sold as a household good in New Zealand.

- in farmacies: iodine solution, potassium permanganate, hydrogen peroxide, glycine, glycerol, ascorbic acid, glucose, activated carbon etc.;

- in food stores: salt, sodium hydrocarbonate, starch, sugar, aluminum foil, charcoal, acetic acid, citric acid, food dyes etc;
- in household stores: hypochlorite solution, sodium carbonate, sodium phosphate, acetone, xylene etc;
- in farming stores: copper sulfate, iron sulfate, urea, sodium and potassium nitrate etc.
- in building stores: copper and aluminum wires, lime etc.

The glassware can be bought also in household stores, as well as gas torches or burners for heating.

Marketplaces greatly widen the list of available reactants and glassware. One can easily buy on Aliexpress or Amazone very different chemical goods – from test-tubes to autoclaves. The author bought on Aliexpress different chemicals up to elemental selenium and tellurium. However, it takes a long to deliver goods from some marketplaces, especially from the overseas.

When the experiments become diverse or complicated, buying all the necessary equipment and consumables requires much time from the student. This problem can be solved by the kits for household experiments. They are widely used [19-21]. The author had elaborated and the kit "Young Chemist" (Fig. 1) at 1999 for household experiments guided just by a manual. It contains simple equipment as test-tubes or evaporating dish and 27 reactants allowing to conduct 145 experiments.

It has been selling since that time in amount of 5-10 thousand a year. After COVID pandemic it turned to be a good support for the distance learning courses.

Fig. 1. The kit “Young Chemist”.

Organizing a course, one should decide whether the students will rely on the household materials or use specific kits (Fig. 2). If one uses household goods or kits external manufacturers, they will determine the list of possible experiments and consequently the list of concepts that could be delivered. It restricts the possibilities of the course. This approach is suitable for outreach courses, non-systemic teaching or for teaching the concepts related to household processes. But it hardly works when we need to create a distance learning course for the systematic course. Then one should use reverse order: elaborate the course, compile a list of experiments, assemble a list of equipment, and launch its production. It is much more difficult and needs production facilities. However, the kits adapted to specific courses (predominantly for high schools) are described [22]. We produced the specialized kits for the topics “Hydrogen and oxygen”, “Dissociation” and “Redox reactions” (Fig. 3).

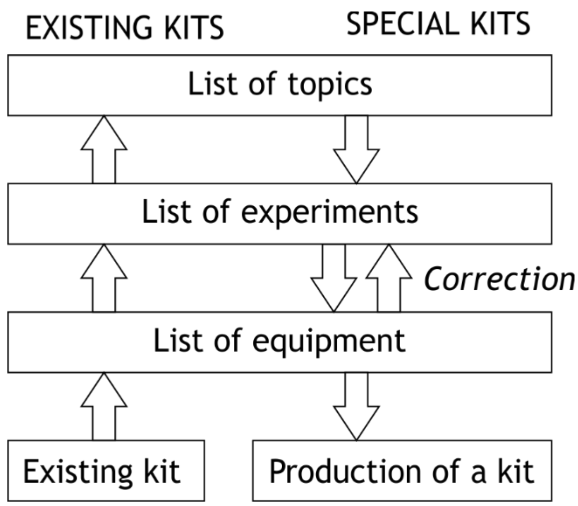

Fig. 2. Workflows for elaboration of a course employing household labs.

Fig. 3. Specialized kit “Redox reactions”

Whether we count on just household goods or use kits, some household equipment is necessary. It is listed below.

- Plastic or oilcloth tablecloth (to protect the table from the reactants and flame).
- Bottle with water (to make solutions or to extinguish fire if something goes wrong).
- Glass cane for wastewater.
- Kettle with the hot water (if slight heating is necessary).
- Small beakers of glass or of polypropylene (to dissolve substances or conduct reactions in solutions).
- Porcelain saucer (to conduct the drop reactions).

- Metallic ashtray (to heat objects over it or to put hot objects on it).
- Pliers or iron tweezers (to hold hot things)
- Toilet paper (to wipe out the rubbish or remove drops of water from the glassware).
- Iron spoon (to heat substances in it).
- Rubbish bin.

SYNCHRONOUS VS AYNCHRONOUS EXPERIMENT

There are two general modes of the distance learning: synchronous and asynchronous [23]. In synchronous mode all students and the teacher attend the session at the same time and the teacher guides the students' activity in "real-time". The teacher instructs, shows the procedures, comments, asks questions watches what the students do and, what is the most gives immediate feedback

In asynchronous mode, the students study whenever they want. The teacher sends instructions (illustrated text or video); answers written questions (not immediate) and comments the reports (if the students sent them – also not immediate). Asynchronous mode has many advantages:

- students work on the suitable schedule;
- students work on their own pace;
- students have possibility for side experiments;
- prearranged instructional materials require much less time than alive instructions;

- doesn’t require good web-camera and strong Internet connection;
- almost has not restrictions for the amount of the students;
- does not overburden the teacher with different activities in one moment.

Moreover, asynchronous mode requires mush less teachers than synchronous (and even than face-to-face learning) thus good asynchronous courses can ease the shortage of the qualified teachers.

Synchronous mode is very difficult for a teacher. At the same time the teacher have to conduct experiments, manage the camera, switch the windows between the students, watch what the students do and react on their actions… The author’s experience shows that after 1.5 hour session he needed to have a rest al least for half an hour. However, synchronous mode has one advantage that often overweighs all the advantages of asynchronous mode: the student gives immediate and personal feedback. The choice between the modes is after the students.

The organization of synchronous and asynchronous mode is completely different and will be described separately.

To conduct a synchronous session the students should get a list of equipment and consumables 3-4 days before. The teacher needs at least an idea what will the students do. However the written synopsis of the session, containing the list of the questions and the blank fields for the answers is also favorable. The written instructions for asynchronous sessions can be used instead of the synopsis too.

To conduct the sessions, we used Zoom. The common workflow is the following.

- The teacher asks to conduct an experiment and shows the preparatory operations (taking test-tubes, adding reactants and so forth, but avoiding showing the final study, when the effect should observe. For example, exploring decomposition of sodium hydrocarbonate in water the teacher puts hydrocarbonate in a small beaker, adds water, dissolves, and takes a can and a kettle with boiled water.
- The students repeat the operations after the teacher. The teacher watches the processes via their cameras (Fig. 4). He corrects the errors of the students, comments the good steps and answers numerous questions. For example, “what to do if I have a mug instead of a beaker». Very often the students (the age doesn’t matter), ask when to stop adding reactants or what to do if something goes wrong.

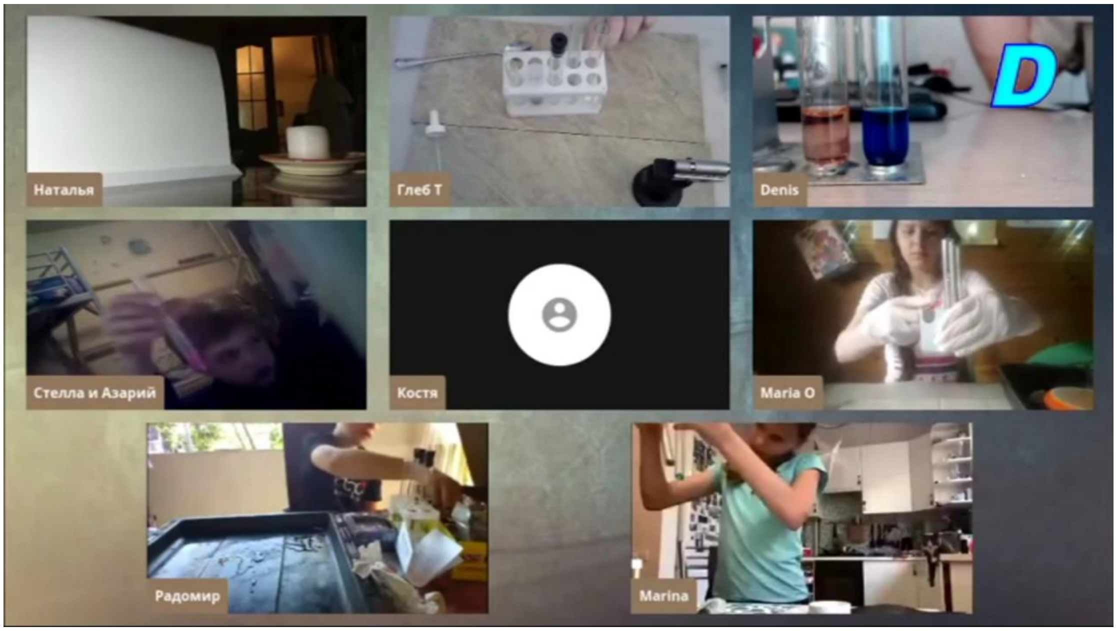

Fig. 4. A typical screen during the synchronous session.

- The teacher tells what to do to complete the experiment and completes it himself. In our examples he pours the hot water into a cane, put a test-tube there and attracts the student's attention to the test-tube. Then the teacher asks the students what they observe, comment the observations and compare the results of different students.
- The teacher asks the questions to provoke a discussion "what has happened". In our example – what gas was observed, could it be a boiling of water, how to check the suggested hypothesis.

- After discussion the teacher sometimes should follow the discussion, for example trying to implement the students' ideas (for example, to put a test-tube without sodium hydrocarbonate into hot water and watch, whether the gas releases.
- At the end the teacher explains what has happened and gives some theoretical ideas. In our example – that hydrocarbonate decomposes into sodium carbonate, water, and carbon dioxide.
- Then he can ask a question how to check this explanation (for example, how to distinguish sodium carbonate from sodium hydrocarbonate).

This scheme is ideal. In reality there are many disruptions. The most widespread are the following.

- The students don't switch on their cameras.
- The students don't ask the questions.
- The students take side activities.

If all the students don't switch on the camera so the teacher can't see and comment what they do, the time for the same activity shrinks l least twice, but nobody knows about the effectiveness of the activity.

Asynchronous mode demands instructional materials – both video and text with illustrations. Videoinstructions are better to demonstrate manipulations. However, if we use videoinstructions, we should incorporate there questions and explanations also – otherwise the student will have to switch between video and text that overloads the working memory (split-attention effect [24]). On the other hand, the text instructions are also necessary because it is much easier to ask information in text, than in video.

To prevent overloading the working memory the instructions should give the information by portions and then ask questions to let the information be proceeded and transferred into the long-term memory. Bearing in mind that the asynchronous mode doesn’t provide immediate feedback the workflow for it is much easier than for the synchronous mode.

- the student performs the experiment that is described in the instructional materials (“what to do”);
- the student observes the results of the experiment under the guidance of the instructions (“where to look at”)
- the student thinks about the results answering the questions in the instructional materials (“which questions to answer”);
- the student gets explicit theory or concept from the instruction.

If we expect the students to conduct experiments themselves, we conceal the results in the video instructions and illustrations.

There is a common mistake to use videorecords of the synchronous session as instructional materials for asynchronous. It is a bad solution because the videorecord takes three times much time than the instruction recorded according to the prescribed scenario. Too much time is taken for pauses, stumbling, thinking what to say, repetitions, individual discussions etc. Even cutting of all those episodes the time of the record shrinks twice. The prescribed scenario requires at least one day of

The text instructions contain the list of equipment and consumables; the safety precautions; instructions what to do; the questions with blank fields for answers; the theoretical commentary. We use different text styles (font color and background color) for all that blocks. The compromise format for the electronic instructions (that is easy to compile and easy to use on the desktop computer) is the *.pdf form. The reasonable dimension of the instruction for 45 minutes is two A5 pages with font size 12 plus illustrations.

The problem we face using written instructions is the functional reading – even 14-15 y.o. students sometimes don't possess this skill.

CONTENT OF THE COURSES

Within any course we develop many manipulative skills. We use the scaffolding learning approach. First, we describe simple manipulations in details (take the test-tube; using a spoon put there a substance for 1 cm by height; take the neck of the test-tube by a clamp; hold the test-tube at the angle 90°…”. When we see (or suppose) that they gained the necessary skills we just point the manipulation (“heat the substance”) and develop more complicated skills (for examples distillation or melting metals). Here is the list of elemental skill that we form within any beginning course:

- mixing;
- dissolving substances;
- heating;
- measuring temperature;
- weighting;
- obtaining and collecting gases;

The complex skills are much more diverse including:

- reactions in solutions;
- filtering;
- melting substances; preparing alloys of fusible metals;
- solid state reactions;
- distillation (from heated to a cold test-tube);
- extraction (using syringes).

The development of the manipulative skills is not as easy as one can expect. The students make numerous stupid and unexpected mistakes even when the teacher shows all the manipulations and draws their attention to all the subtleties. For example, very often the students

- don’t stir the substances after mixing
- don’t understand when a substance dissolves and when doesn’t dissolve
- heat anything but the substance
- don’t understand when to stop heating
- don’t understand how much substance to add.

Here is the example of an introduction course. It’s aim is to get the 11-13 y.o students acquainted with chemical substances and processes. It consists of three partly independent blocks (to let the students join the course at any block).

Block 1. Chemical and physical processes.

1.1. Temperature and heat exchange (teaching how to heat substances).

1.2. How substances behave while heating (classification of phenomena).

1.3. Mixing of liquids and what prevents it (teaching how to mix substances; introducing the concepts of solubility, density and diffusion);

1.4. Solutions and dissolution (introducing the concept of solution and solubility; teaching how to make solutions)

Block 2. Objects of chemistry.

2.1. Candle (getting acquainted with burning and melting).

2.2. Metals around us (the general properties of metals: electrical conductivity, polishing, melting).

2.3. Surface (getting acquainted with the properties of surface, contact angle, adsorption).

2.4. Shaping materials (teaching how to add a shape to a material: casting, stamping etc.)

Block 3. Substances (getting acquainted with the variety of the properties).

3.1. Household and washing soda.

3.2. Iodine.

3.3. Potassium permanganate.

3.4. Hydrogen peroxide.

The promising idea of the self-assessment was a practical homework. The students can perform the practical task such as making a heart of a paraffin, estimating the concentration of a substance to feel its taste, obtaining hydrated sodium chloride $NaCl \cdot 2H_2O$, cleaning the surface of a coin etc. The teacher doesn't need to assess the performance: the children will see their success (or failure) themselves.

CONCLUSION

It is very possible to broadly implement the household experiment into the chemistry course, at least for the secondary school students. It can be performed in synchronous mode (the teacher shows the manipulations, watches what the students do and provoke discussions in real time) or in asynchronous mode (the students work using video- and textual instructions). Household reactants and glassware as well as specialized kits for household experiments can be used.

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