Reflection

An Entertaining Lesson for Paediatric Oncology Patients: Learning Natural Science through Play and Demonstrating Chemistry and Physics Experiments

Jeran Marko[1,‡,*], Jazbec Janez[2], Pokorn Marko[3], Kores Mihaela[2], Kitanovski Lidija[2,‡]

1. "Jožef Stefan" Institute, Department of Inorganic Chemistry and Technology, Ljubljana, Slovenia
2. Department of Paediatric Oncology and Haematology, University Children's Hospital, University Medical Centre Ljubljana, Ljubljana, Slovenia
3. University Medical Centre Ljubljana, Division of University Children's Hospital, Ljubljana, Slovenia

‡ These authors (J.M & K.L.) contributed equally to this work

* Correspondence: Jeran Marko, marko.jeran@ijs.si

Abstract:
Experimental work plays an important role in learning the natural sciences (chemistry, physics and biology). It is also an important tool in various interdisciplinary fields. Many natural laws and phenomena of everyday life can be observed through simple chemical and physical experiments. With the help of a researcher from a scientific institution, we transferred the described concept from ordinary classrooms to a hospital environment, namely in the Clinical Department of Paediatric Haematology and Oncology of the University Children's Hospital in Ljubljana (Slovenia). A dynamic interaction was found that motivated the young patients to learn science in this way. Through their active participation in challenging diagnoses, they can immerse themselves for a moment in effects that literally enchant them. In addition to curiosity and creativity, cooperation and teamwork were also encouraged.

Keywords: Experimental work, Natural sciences, Paediatric haematology and oncology, Learning, University Children's Hospital, Motivation, Curiosity

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1. Introduction

At the Division of Paediatrics – University Children's Hospital, University Medical Centre Ljubljana, the diagnosis and treatment of cancer as well as peripheral hematopoietic stem cell and bone marrow transplantation in children and adolescents up to the age of 18 or until the end of schooling is carried out. This institution is also performing sophisticated diagnostic and therapeutic procedures for children and adolescents with non-malignant blood diseases and blood clotting disorders, severe forms of congenital immunodeficiencies and some congenital metabolic disorders. Advanced forms of treatment, including immunotherapy such as CAR-T (*Engl.* Chimeric Antigen Receptor) are introduced and implemented. Annually 80-90 patients with newly diagnosed cancer are treated and an average of 10 transplantations are carried out (University Medical Centre Ljubljana, n. d.).

Treatment of paediatric cancer requires close multidisciplinary cooperation with various laboratory specialities and clinical subspecialties. Therefore, close cooperation among different subspecialities is essential and established, not only within the University Medical Centre Ljubljana (UMCL), but also with the University of Ljubljana, Faculty of Medicine and Institute of Oncology in Ljubljana. Radiotherapy of children is performed at the Institute of Oncology, where treatment is performed by radiotherapists dedicated to paediatric radiotherapy. When proton irradiation is preferred, it is performed at the Proton Center in Trento, Italy, with which a multi-year exemplary collaboration has been established (University Medical Centre Ljubljana, n. d.). In this case, all costs of treatment abroad and accompanying parents are covered by the public health insurance company and are not a burden on the family (University Medical Centre Ljubljana, n. d.).

The Department of Paediatric Oncology and Haematology is a member of the European Reference Network for Paediatrics Oncology (ERN PAEDCAN) (University Medical Centre Ljubljana, n. d.), International Organization of Paediatric Oncology (SIOP), European Society of Blood and Marrow Transplantation (EBMT) and Berlin-Frankfurt-Münster Group (BFM group). Within the framework of these professional organizations, it is involved in international academic research in the field of treating children with cancer. Active research participation in some of the European Union projects (EU projects) is carried out. Quality comprehensive treatment is key to the successful treatment and rehabilitation of children treated for cancer. Three psychologists, one dietician and one physiotherapist work in the department (University Medical Centre Ljubljana, n. d.). Tight and regular cooperation with the National Institute of Rehabilitation, Ljubljana is established (University Medical Centre Ljubljana, n. d.).

Children and adolescents treated at the Department of Paediatric Oncology and Haematology are also involved in the hospital kindergarten and school. During the stay of the child in the hospital, the education takes place in the hospital and is carried out by the teacher of Ledina Hospital school, Ljubljana. Whereas, when the child is at home, the teaching is carried out by the teachers of the school the child attended before the illness. Funds for individual teaching at home, are provided by the Ministry of Education based on a decision, issued by a special commission, to which parents address their inquiries (Žugman, 2021). The majority of children in Slovenia complete school regularly, despite a long-term illness (Kandus, 2023).

The hospital school departments within the Ledina Primary School (Ljubljana, Slovenia) have existed since 1958, and school work in the hospital began in Ljubljana in 1951 (Ledina hospital school, n. d.). Today, the entire hospital school consists of 23 different departments, in which 23 teachers teach. Around 2,700 primary school pupils attend the school every year, 600 of whom are secondary school students. They are taught individually by the hospital teachers in the general education subjects. The secondary school pupils and students attend the school to make their stay in hospital more varied and enjoyable and, above all, to make it easier for them to integrate into the life and work of their school when they return from hospital. Due to the treatment methods for certain diseases, some students come from home to attend school at the hospital; and for some, the hospital teachers come to their homes and teach at home, the latter mainly with the help of information technology (Ledina hospital school, n. d.).

Pupils and high school students who attend the hospital school over a longer period of time are also assessed (oral and written knowledge tests, seminar papers). Everyday school life in the hospital takes place in small groups and the learning process more often takes place on individual level. Frequently lessons take place in patients' rooms, at their bedsides. The pupils and students also enjoy many school activities – special cultural, scientific and sports days, creative activities, various workshops, from cooking to poetry, visits from famous singers, actors, athletes, poets and writers as well as excursions, etc. (Ledina hospital school, n. d.).

This paper will present the enrichment of the day in the hospital with experiments in chemistry and physics. By conducting a lecture and by demonstration of experiments, the cooperation with scientific research institution in the transfer of knowledge, with the method of interdisciplinary knowledge integration of scientific content was presented to the pupils.

2. Practical activity

The thorough practical part consisted of building the triangle of members of the system (**Figure 1**). The researcher of the scientific research institution led the discussion between the young patients and the staff of the department. Fundamental concepts from the classical educational process and their application in real life situations were incorporated through the presentation. In our case, the parents of the primary school pupils were also involved and have actively participated in the discussion. Doctors and nurses were involved in some experiments.

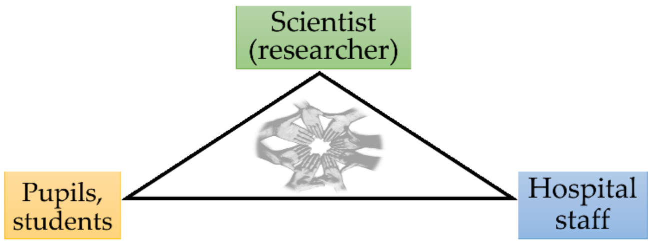

Figure 1. Triangle of cooperation in the implementation of the educational day in the hospital department.

2.1. Air and its components – physical experiments

The active and dynamic collaboration of all participants began with the topic of air. The discussion focused on the components of air and their isolation. A large proportion of the participants knew the composition of the gasses in the air. After the theoretical background, the important components of air were demonstrated in practice.

The young people were most enthusiastic about liquid nitrogen. Through simple experiments, we found out what the extremely low temperature of −196 °C means in practice. Some interesting experiments should be mentioned here. The participants had not expected that the balloon deflated in liquid nitrogen would return to its original state at room temperature (molecular dance in motion). When the balloon is at room temperature, the air inside moves quickly and takes up a lot of space. When the balloon is cooled by the liquid nitrogen, the air inside moves much more slowly as it loses heat to the liquid nitrogen. This causes the air inside to condense and the balloon can "deflate" and fit into the thermos flask. After the balloon has been pulled out, the air inside heats up again and expands the balloon back to its original size (Liquid nitrogen, n. d.). We also made a banana hammer. When a banana comes into contact with liquid nitrogen, the water in it quickly freezes and turns to ice, making such objects "rock hard". They can use it to hammer nails into a wooden base.

By interpreting the Leidenfrost effect on the skin, we have established that liquid nitrogen is extremely cold and that our body is extremely warm compared to liquid nitrogen. There is a big difference between body temperature and the temperature of liquid nitrogen. When liquid nitrogen comes into contact with our hand for the first time, part of the liquid immediately turns into gas. The rest of the liquid lands on this layer of gas and rolls on without ever touching us. This effect only works if the hand is not exposed to the cold liquid for long. Prolonged exposure can cause the gas layer to escape, which can lead to frostbite or worse. Due to the working conditions described above, we must wear suitable protective equipment when experimenting with liquid nitrogen (Liquid nitrogen, n. d.). Special gloves are necessary, because classic laboratory gloves become very sensitive on contact with the gas and can cause skin ulcers. By demonstrating the effect of liquid nitrogen on classic laboratory gloves, we can also demonstrate the fragility of such materials.

Following on from the other experiments, we also investigated what happens when we try to seal a bottle containing a small amount of liquid nitrogen with a plastic stopper. When liquid nitrogen is trapped in a sealed bottle, the gases in the container begin to expand as it constantly boils and the pressure in the bottle increases. Approximately one ml of liquid nitrogen turns into 700 mL of nitrogen gas (Tretiakov, 2014). The force blows the cork away from the bottle opening. The alternative demonstration with the bottle, in which a hole is drilled through the cork and it can be observed how the nitrogen escapes through the hole, was also demonstrated. The effect is similar to the fountain – in our example, the nitrogen fountain.

Figure 2. Demonstration experiments with liquid nitrogen: (**a**) cold vapours of liquid nitrogen can already be felt with the hand near the container, (**b**) Leidenfrost effect of liquid nitrogen on the skin and (**c**) gas leakage through the capillary: nitrogen fountain (Photo: Alenka Klun with permission of the University Medical Centre Ljubljana).

2.2. Chemical reactions

By demonstrating chemical reactions, the visitors learned about chemical reactions in nature and deepened their knowledge of them. It was also considered when the chemical reaction takes place.

Fire is a chemical reaction in which a fuel and oxygen are converted into carbon dioxide and water. It is an exothermal reaction, *i. e.* a reaction in which heat is generated. The reason for this is that the chemical bonds in the oxygen molecule are relatively weak and the newly formed bonds are more stable – so there is a net production of energy (NewScientist, n. d.). The general combustion equation of fire is (**Eq. 1**):

$$\text{Fuel} + \text{oxygen } (O_2) \rightarrow \text{carbon dioxide } (CO_2) + \text{water } (H_2O), \quad (1)$$

a theorem that was drummed into many of us by our teachers at school. However, the combustion reaction does not proceed directly from oxygen to carbon dioxide. Instead, a whole series of intermediate molecules are involved along the way. Sometimes incomplete combustion occurs, in which these intermediate molecules are formed in unusually large quantities (New Scientist, n. d.). This model was used to demonstrate the combustion reactions of everyday ingredients – absorbent cotton and dry bread. The visitors were then able to observe the combustion of the aforementioned oxygen-enriched raw materials. The greatest wave of enthusiasm was triggered by the oxygen-enriched absorbent cotton (nitrocellulose), which caught fire very quickly. All of the absorbent cotton was converted into gaseous products, resulting in complete combustion. This was followed by a demonstration of the northern lights, a chemical reaction in which kitchen aluminium reacts with hydrochloric acid with the addition of copper(II) sulfate pentahydrate. The reaction produces hydrogen gas, which colours the flame green due to the copper ions present (Fleming, 2014).

Also we considered the production of light in nature and its application in chemical laboratories. In general, the type of luminescence is defined by the type of energy emitted. Bioluminescence often occurs in nature when an enzyme catalyses the oxidation of a substrate molecule (*e. g.* in fireflies; enzyme: luciferase, substrate molecule: luciferin) (Marinko et al., 2024). Light can be used for defense or attack, for communication, for mating or simply to illuminate the environment. Two phenomena of photoluminescence are known: fluorescence and phosphorescence. Fluorescence is a photoluminescent phenomenon that occurs under a constant supply of energy (usually in the form of radiation), while phosphorescence can persist even if the energy supply is interrupted (Jeran et al., 2020*a*; Jeran et al., 2020*b*). The fluorescence of various dyes was presented, including fluorescein, which occurs in fluorescent markers. Chemiluminescence is the generation of electromagnetic radiation in the form of light through a chemical reaction. In this type of luminescence, light generation of light was demonstrated in the reaction of forensic luminol and hydrogen peroxide. Due to the enthusiasm of those present, it was necessary to repeat some of the lighting effects (**Figure 3**).

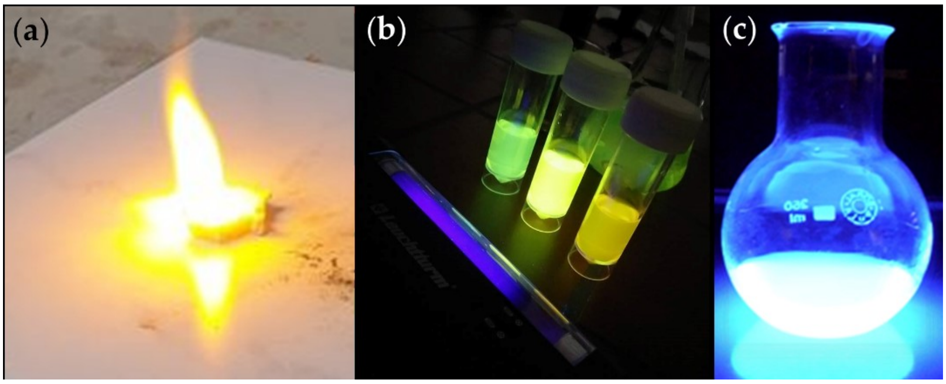

Figure 3. Demonstration of lighting effects: (**a**) ignition of bread, (**b**) fluorescence of fluoresceins and (**c**) chemiluminescence of luminol with diluted hydrogen peroxide solution (Photo: Marko Jeran).

There was also a colourful party with lollipops. When the lollipop dissolves in the sodium hydroxide solution containing manganese, at least five different colours can be distinguished, corresponding to the different oxidation states of the manganese. In a series of redox reactions, electrons are continuously released from the glucose to successive manganese compounds. At each step in this chain, a colour change becomes visible. Manganese is ideal for this experiment because it has more stable oxidation states than any other transition metal (from +2 to +7), each of which has a different colour (Prolongo and Pinto, 2018).

Beer was produced using detergent and an aqueous solution of potassium iodate (KIO_3) and a solution of sodium sulfite (Na_2SO_3) in sulphuric acid with the addition of ethanol. The contents of both solutions were simultaneously poured into a beaker in which "beer" was formed. We waited about 15 seconds for the "miracle", as the reaction took place with a slight delay. The participants thought this was a mistake. The yellowish-brown colour of the "beer" came from the precipitated iodine and the foam from the detergent.

At the end of the demonstration, we asked a little fighter, who was celebrating his 4th birthday that day, to stand in front of the experiment table. We all congratulated him and wished him well, but he was keen to experiment for himself. Using an aqueous solution of iron trichloride ($FeCl_3$) and a cotton bud, he made a drawing and wrote the text on the filter paper (**Figure 4**). The invisible writing and drawing were made visible by spraying with potassium thiocyanate (KSCN). The experiment is also known as artificial blood (blood magic), in which a reaction takes place between the two reactants, resulting in the formation of dark red iron(III) thiocyanate ($[Fe(SCN)_3]$) (**Eq. 2**) (MEL Science, n. d.).

$$FeCl_3 + 3\ KSCN \rightarrow Fe(SCN)_3 + 3\ KCl \quad . \qquad (2)$$

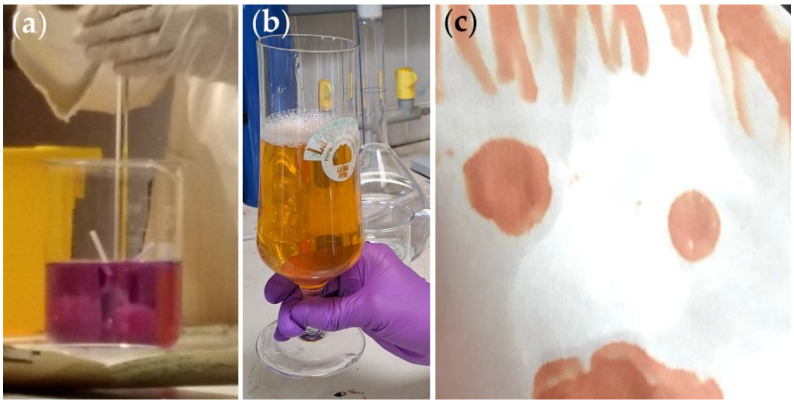

Figure 4. Demonstration of: (**a**) the course of a redox reaction between potassium permanganate and sucrose (lollipop) in a basic solution, (**b**) chemical beer and (**c**) an art work product after the reaction of iron trichloride and potassium thiocyanate (Photo: Marko Jeran).

3. Conclusions

Experimental work plays an important role in learning the natural sciences (chemistry, physics and biology). Many natural laws and phenomena of everyday life can be observed through simple chemical and physical experiments. From the interaction between all those involved, it can be concluded that this method of imparting knowledge has proved its worth in hospital work. In addition to this type of learning, we also organized entertainment for the young people, which they really need with such demanding diagnoses. For a moment, they can indulge in effects that literally enchant them. In addition to curiosity and creativity, we have also promoted interdisciplinary cooperation and teamwork.

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Conflicts of Interest: The authors declare no conflict of interest.

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