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How Diverse Chemistry Lessons Can Contribute to the Active Role of Students

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Abstract: Diverse chemistry lessons can encourage active involvement of students. This article presents practical examples of creating diverse lessons with student involvement through interdisciplinary linking with art lessons, developing and strengthening ICT competencies, and experimental work. Such an approach to teaching and learning consequently creates inquisitive and motivated students, and stimulates students' interest in chemistry.

Key words: chemistry education, chemistry, creativity, e-materials, experimental work

1. Introduction

Chemistry is a key natural and experimental science that studies substances, their structure, properties and changes (Curriculum, 2011). Aleksandra Kornhauser Frazer notes that the information revolution has transformed education. Former tendencies of trying to acquire as much accessible knowledge during the educational process are outdated (Kornhauser Frazer, 2018). Today knowledge is widely available, immense and fast-growing, so the portion of the entire world knowledge that the human brain can learn is smaller by the day, and traditional learning paths lead only downwards (Kornhauser Frazer, 2018). A new approach is needed that will facilitate the development of the backbone of our knowledge, the key structure onto which new realisations can be pinned, as well as the recognition of patterns of knowledge and the ability to predict and forecast new knowledge, including opportunities for targeted search for information that helps build and complement new ideas (Kornhauser Frazer, 2018). Developing diverse and, in terms of the role of the students, active, dynamical lessons gives numerous opportunities for achieving educational aims through experimental, hands-on forms of learning. These are essential for building up understanding, long-term embedding of knowledge, interlinking this knowledge, and for the use of often abstract chemical terms. The article concentrates on how and by what means we can encourage active involvement of students, making chemistry lessons more diverse and at the same time more motivating.

2. Quality Teaching and Knowledge

Active learning is one of the factors that leads to quality knowledge and general education. Quality knowledge can be defined as well-structured and in-depth knowledge that the student comprehends and knows how to apply (in explaining natural and social phenomena, in relationships around them, and in solving problems)

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(Outline for Curriculum Revision, 2022).

Quality teaching and learning are processes that cannot be realised without simultaneously encouraging hands-on, active learning (Outline for Curriculum Revision, 2022). Every kind of learning, even the simplest cognitive activities, involve, as the name suggests, a certain measure of active involvement (Outline for Curriculum Revision, 2022). By emphasising active learning we aim especially at the student including into creating and building knowledge as much and as many appropriate cognitive or thought processes as possible, for example, observation, classification, abstraction, inference, etc., with the help of which the student gradually — more efficiently than if this is done instead of them by the teacher offering a ready explanation — internalises the knowledge and secures it at deeper taxonomic levels (knows how to utilise it, link it, interpret it, evaluate it etc.) (Outline for Curriculum Revision, 2022).

Barica Marentič Požarnik states that the most important characteristic of quality knowledge is knowledge with understanding. Understanding means going beyond the given information and responding with flexibility to specific circumstances (Marentič Požarnik, 2020).

3. Active Teaching and Learning

Education experts see teaching as a complex and demanding activity that requires critical thinking and a commitment to lifelong learning (Borko, 1989; Peterson & Comeaus, 1989, as cited in Woolfolk, 2002). Teaching strategies that encourage students to active participation and lead to higher levels of initial learning are linked to longer retention of the knowledge gained (Woolfolk, 2002).

Woolfolk (2002) defines active teaching as instruction characterised by high levels of teacher explanation, demonstration and interaction with pupils.

It is noted in the 2022 Outline for Curriculum Revision at Primary and Secondary Schools that active learning is associated with the experiences of students and learning from specific life circumstances, allowing students to obtain new knowledge through their own activities. With active learning the student is in the forefront and the teacher needs to organise a learning environment that encourages students as much as possible (Outline, 2022).

Active lessons are integrated lessons in which the teachers and students discuss what the final results of these lessons will be and this directs how the learning process is formed; in this process the mental and physical work carried out by students is balanced (Jank & Meyer, 2006). “Physical work” is defined as all the material activities that we conduct with the help or use of our body, “mental work” are all the cognitive activities (linguistically articulated or mental processes) (Jank & Meyer, 2006). In the process of teaching and learning, the mental and physical work of students is thus dynamically linked (Jank & Meyer, 2006).

Pace management is keeping a suitable (flexible) pace during lessons and group work, with smooth transitions between various activities (Woolfolk, 2019). An effective teacher avoids sudden transitions such as announcing a new activity before they have the attention of the students, or initiating a new activity while the students are still in the middle of the previous one (Woolfolk, 2019). In such situations, a third of the class will embark on the new activity, most of the students will still be working on the previous one, a number of students will start asking their peers what they are supposed to be doing, some will take the opportunity to have fun, and most will be confused (Woolfolk, 2019). The second problem of transitions is slowing down or devoting too much time for the beginning of a new activity. Sometimes teachers tend to give too many instructions (Woolfolk, 2019). Woolfolk also states that

problems can also occur when only one student is given an active task at any one time, while others are expected to watch and wait for their turn. A teacher who is successful in terms of awareness, overlapping activities, focusing on the group and managing the pace will maintain a class in which the students will be active and not escape the teacher's watchful eye (Woolfolk, 2019).

It is important that the gained knowledge enables students to actively solve problems and challenges in new circumstances, and helps them in connecting or embedding diverse learning contents.

Marentič Požarnik defines *transfer* as one of the key concepts in the theory of teaching and education in general. Transfer of learning is thus the transferal of the outcomes of previous learning to further learning, from one subject area to another, and also from one set of known circumstances, e.g., school, into new ones - life and work (Marentič Požarnik, 2003). Woolfolk states that students will probably accomplish the transfer of information into new situations if they are actively included in the learning process. Students need to be encouraged in abstract reasoning in order to be able to utilise this knowledge later. Greater transfer can also be achieved through excessive study in which we train a skill even after it has been acquired (Woolfolk, 2002).

If we wish science learning to be constructive, we need to ensure that students reflect on their learning, that approaches to learning are meaningful, that they relate what they are learning to their previous experiences or prior knowledge, that they follow their level of understanding the relevant concepts and that they are capable of expressing their feelings about what they learn (Gunstone & Mitchell, 1998, as cited in Devetak, 2014). This is why active forms of learning are important in science learning, allowing students to reflect upon the content they are learning, encouraging effective learning (Gunstone & Mitchell, 1998, as cited in Devetak, 2014).

Lessons should be designed to help students construct more relevant concepts and dismantle inadequate ones, as well as trigger cognitive conflict where necessary (Marentič Požarnik, 2020).

4. The Active Role of Students in Diverse Chemistry Lessons — What Practical Experiences Have Demonstrated

Chemistry lessons are based on an experiential, experimental-research and problem-based approach that contributes to understanding of the sciences and a positive attitude to chemistry and science (Curriculum, 2011).

In chemistry lessons students focus preferentially on: comprehending the interdependence of structure, properties and uses of substances, comprehending natural processes and types of chemical investigation of nature, a responsible attitude to using substances, the ability and willingness to act with commitment, responsibility and reason towards health and environmental issues (chemical safety), experimental-research skills, scientific processes and cognitive processes, critical thinking, creativity, spatial perception or the basics of chemical visual literacy with visual means or modern ICT, and on scientific literacy (Curriculum, 211).

In learning and comprehending chemistry, what is important is content (concepts, facts, models, theories) as well as processes and methods through which knowledge is gained (Curriculum, 2011). Experience shows that students like being active during lessons, carry out experiments, participate in smaller groups, and are for such work (far) more motivated, while they are less motivated for work at a submicroscopic or symbolic level. One of the challenges is how to preserve a high level of motivation with students also for chemical concepts at these levels. Comprehending certain chemical contents can be rather abstract and hard for students, so hands-on learning is important, because concrete experience during lessons is very useful. Students need to be taught and get used to the necessary linking of theoretical and practical knowledge that they can deepen, consolidate and

build on in various ways.

The article presents a few practical examples of how and in what way diverse chemistry lessons can contribute to the active role of students. The pandemic disrupted our plans in a number of ways and forced us to learn new approaches and strategies.

Interdisciplinary integration is one of the key concepts of modem guidelines in educational development (Curriculum, 2011). It is essential for the transfer or integration of knowledge and skills (Curriculum, 2011). In chemistry lessons we tried an interdisciplinary link with art classes; this was not limited to a single project but the essence was that it continues, expands or is carried out in different ways over the years. It is important to encourage student creativity during lessons. Woolfolk defines creativity as innovative, original thinking or problem solving, creativeness. Although art lessons are often linked to creativity, we can take a creative approach to anything (Woolfolk, 2019). Students were given a task in which they had to find, read and copy out the properties of a chosen chemical element from literature or the internet. In art classes they then drew the symbol of the chemical element in a way that their drawing showed the element's use. A collection of their beautiful creations was presented in e-book form. The students impressed us with their exceptional creativity in their drawings. In small groups during art classes they created models of the atom out of wires and pearls. An animation about the structure of the atom that had been created for the needs of distance learning during the pandemic was this year utilised for the visualisation and additional consolidation of knowledge at home. In the past we prepared a variety of teaching aids for chemistry lessons (e.g., wooden blocks for building formula units of ionic compounds). During distance-learning the students had the opportunity to create these aids at home with the help of a template (e.g., making the aforementioned blocks out of paper). The concepts of social as well as knowledge interaction are very important these days. Each class made a monomer model of the chosen molecule during art class. Then each student made an individual section of a polymer chain and the class together were able to form and depict the polymer molecule. We also prepared two original didactic games for the students — *The Adventures of Chem and Istry 1 and 2* — which allow students to consolidate and deepen their knowledge of the selected contents in an educational and entertaining way through examples of genuine tasks. The main characters of the aforementioned didactic game are teenagers Chem and Istry who love chemistry and want to reach their lab as soon as possible (the target of the game). Due to specific circumstances (Covid-19) we got the idea of preparing diverse e-material based on the games created. We thus transformed genuine tasks and questions from a didactic game into e-challenges that students were able to solve with the help of their computer or tablet, e.g., solving tasks in smaller groups where the correct answer was the prerequisite that allowed them to move on to the next challenge. This way the teacher also had instant feedback. With the use of ICT we encouraged and developed spatial perception and the use of visualising elements (models, submicroscopic presentations, animations) with students. Chemical models are systematically used in thematic units and phases of chemistry lessons (Curriculum, 2011). Students were also able to make models out of plasticene clay or salt dough at home. They are very skilled in the use of ICT but what is important is that the teacher rationally assesses in what way ICT is included into the lesson and how to monitor student feedback. An original story about a seal teaching a fox how covalent bonds are created is enhanced with illustrations in which, for example, a scoop of ice cream represents the outer or valence electron of non-metals. With the help of the rhyming text and illustrations, students in small groups found out about the formation of covalent bonds.

Experimental work is a key method in teaching chemistry and experience has shown students enjoy a great deal. During distance-learning we prepared and recorded various experiments for students that they were either

able to carry out at home or were shown merely as a demonstration. Recording and editing of these experiments demanded a fair amount of time, especially if teachers were not familiar with this beforehand and at the same time the pace was very fast. In carrying out the experiments at home, students demonstrated a great deal of creativity as well as familiarity with ICT skills. We were thus able, for example, in this school year, to observe how accurately students watched the chosen experiments via video in comparison with carrying out the experiments in front of the students in the classroom. In both cases feedback was monitored through various applications (e.g., Forms, Kahoot…).

Students had chemistry lessons in their own classrooms; the recommendations of the National Institute of Public Health and the school had to be followed, so they were limited in their experimental work and solutions had to be found and a certain amount of flexibility shown. With the students we thus conducted some of the experiments outdoors, in front of the school, and to this purpose also prepared a suitable teaching environment and chose suitable experiments.

For students with an interest in chemistry various afternoon workshops in chemistry were organised in which creativity, ICT and experimental work were usually intertwined with a chosen red thread. The workshops were run in small groups with emphasis on the active role of the students and with the teacher as a moderator of learning content.

There are many opportunities in chemistry lessons for achieving learning goals through diverse practical knowledge that is enhanced by acquiring experience. We observe that in active forms of learning students benefit in terms of knowledge as well as in acquiring communication and social skills and values.

5. Conclusion

In conclusion we list the guidelines and reflect on the activities conducted. In addition to teaching their subject, teachers need to also be capable of leading group activities: directing the students' attention in a group, passing from one point to another and moving from one activity to the next (Woolfolk, 2002). If we wish to include all students into an activity, we need to make sure they all know how they can participate in each individual activity (Woolfolk, 2002). If we wish to reach our aim — making learning accessible to all students, we need to make sure that all students know how to participate in various class activities. This means teaching, indicating and practicing suitable ways of participation (Woolfolk, 2002).

Maintaining a focus on the group ensures keeping as many students as possible engaged in class activities and avoids narrowing the attention to only one or two students at a time (Woolfolk, 2002). All students should be engaged in some kind of activity throughout the lesson (Woolfolk, 2002).

In testing the comprehension of knowledge and group responses, we can utilise coloured cards or certain applications. Smaller groups are constantly changed to ensure that everyone is following the lesson. We also pay attention to possible silent nodding. We need to keep assessing whether the majority of students are following the chosen activities. In an active form of teaching, careful planning of the lesson and aligning the teaching methods to the learning objectives are important. What we must also be aware of is that in reality the teacher often needs to monitor a large number of activities simultaneously and that certain unpredictable situations can also occur. Woolfolk (2002) states that efficient teachers know how to convert their knowledge into examples, explanation, illustrations and activities.

Let us be guided in teaching by the thought of the remarkable chemist Aleksandra Kornhauser Frazer, who states that the teacher's main role is to educate students in effective ways of acquiring knowledge and instil in them a love of learning (Kornhauser Frazer, 2018).

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