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The effects of E-learning units on 13–14-year-old students' misconceptions regarding some elementary chemical concepts

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Abstract: Students' misconceptions in science can lead to a range of learning difficulties if the teacher does not choose the appropriate teaching strategies to reduce their frequency. In this paper, 13–14-year-old students' misconceptions regarding structure and states of matter, pure substances, and mixtures are explored. The teaching strategy with E-learning material was applied to examine its effects on the frequency of misconceptions. The research was conducted in urban schools in Bosnia and Herzegovina with 7th- and 8th-grade students. Findings pointed to the misconceptions originating in transferring the macroscopic observations into the submicroscopic level and in misinterpretation of the size of particles. Students who used E-learning material at school mostly had lower percentages of misconceptions in comparison to students from the control group and students who accessed the same E-learning material from their home. This indicates that the E-learning strategy could have promising results if applied more extensively at schools. This study aims to direct teachers' attention toward applying E-learning in chemistry teaching, for students to gain scientifically accepted knowledge and to reduce the occurrence of misconceptions.

Keywords: structure of matter; pure substances; mixtures; misconceptions; E-learning material.

INTRODUCTION

Four decades ago (in 1982), Johnstone presented his ideas about the three levels of representation of chemical concepts.[1] He suggested that chemical knowledge consists of "at least three levels": macroscopic (visible), submicroscopic (particulate) and representative (symbolic), and represented them with a triangle. Chemistry teaching is not focused on a certain level of representation but placed inside the triangle, since teachers and students are expected to manage them simultaneously.[1] According to Johnstone, chemists were mainly thinking at the

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macroscopic and submicroscopic levels, but chemistry teachers taught students mainly from the perspective of the symbolic level. This meant that the students were not taught to "truly think like chemists".[2]

Experiencing chemistry through demonstrations or laboratory work (macroscopic) and understanding it in terms of atomic and molecular interactions (submicroscopic) promotes the development of conceptual understanding. Among the main characteristics of students who demonstrate conceptual understanding, there is the ability to link macroscopic, submicroscopic, and symbolic levels of representation.[3,4] Therefore, chemistry instruction should emphasize this multilevel thinking.[5]

Many studies showed that students often develop an understanding of how nature is functioning,[6] which is not in line with the scientific meaning of concepts.[6,7] Students have beliefs about physical phenomena derived from prior learning or from interaction with physical and social world.[8] They obtain naive views about matter also through their experiences during childhood which lead them to incorrect ideas.[9] The consequences are incorrect understandings of science concepts and phenomena that affect the integration of new with the existing knowledge,[10] and may persist even after teaching, along with scientifically approved ones, or form a certain kind of synthetic model with them.[11] Misconceptions can be acquired both before and after teaching.[6] Misconceptions formed at school originate mainly from inadequate curricula, teaching material, textbooks[6], ineffective instruction and textbook misrepresentation.[12]

Misconceptions of some elementary chemical concepts – Literature review

To understand states of matter, transitions between them, as well as pure substances and mixtures, the main prerequisite is the knowledge and understanding of the particle (particulate) theory of matter (PNM).[13] Misunderstanding of this theory may hinder learning of other topics such as states of matter.[10] The ability to understand the submicroscopic level is developed gradually with a careful teaching program over a time scale of years.[14]

A large proportion of students' difficulties encountered when moving from everyday thinking to scientific thinking is regarded as the projection of properties from the macroscopic world to the submicroscopic level of representation.[15] Students tend to generate a hybrid macroparticulate model in which particles possess macroscopic properties.[16]

Direct sensory experience leads students to a naive view of matter. They rely solely on sensory information when reasoning about matters up to the age of around 14 years.[17] One of the first published studies[18] on student's conceptions about changes in states of matter (melting, evaporation and condensation) uncovered many non-scientific conceptions among children aged 12–17 years old. Some of the detected misconceptions persisted even after teaching.[18] Students often fail to understand the vibration of particles in the solid state, whereas a majority of them were able to indicate particle movement in liquid and gas states.[19] Students also experience specific difficulties with gases since those they know from everyday life (air) are invisible, which prevents them from forming the concept of gas spontaneously.[17] Research studies regarding the most common misconceptions about states of matter held by 12-, 14- and 16-year-old students suggest no significant difference between the misconceptions held by these different age groups.[20]

The concept of a pure substance is difficult for young learners, but 11–12 year-old students might understand the concept if the appropriate teaching methods were used. The characteristics of pure substances, such as having specific melting and boiling point as well as being composed of only one kind of particles, are too abstract for students at this age.[14] The term pure substance could be deceiving since "substances are just substances – they are not pure and impure substances".[21] The term mixture is also simplified, "wood contains many substances; they are not simply mixed in a random way but built into a complex structure".[21] One of the best ways to induce students' thinking on the submicroscopic level (pure substances and mixtures) is to include particulate drawings into instruction.[22]

E-learning

The impact of E-learning on students' achievement is complex and depends on many factors, but studies showed that students learn best with E-learning when they are interactively engaged in the content. Use of technology significantly improves their performance and shifts a teacher-centred classroom environment to a more learner-centred classroom environment.[23] Web-based educational software improved academic achievement of 7^{th} grade students in Turkey in structure and properties of matter.[24] Findings of this study point to the benefits of these material: 1) web-assisted applications provide limitless time for the replaying option, and they are suitable for an individual's learning speed, unlike the traditional learning environment; 2) rich audio–visual content has positive impact on students' learning; 3) this material has been designed with meaningful learning that requires the connection of new with the previously acquired knowledge.[24]

Research findings confirm that the use of e-units created to connect the three levels of representation of chemical concepts results in improvement of students' achievements.[7] The contents of E-units must also be relevant to the target group of students, and to contain appropriately designed multimedia elements. E-learning units are intended for both independent learning and repetition, as well as for work in the school under the guidance of a teacher.

Some research[25,26] examined the role of the virtual laboratory on 11–12-year-old students' understanding of states of matter, pure substances and mixtures. This virtual laboratory contained all three levels of representation of a chemical concept and dynamic visualizations of the submicroscopic level. The results showed that students, to whom the virtual laboratory was displayed, scored higher in the achievement test than the students who were taught using the teacher-centred approach with static visualisations.[25,26]

EXPERIMENTAL

Research problem

This research was addressed to diagnosing misconceptions of selected science concepts (structure of matter, states of matter, pure substances and mixtures) held by 13–14-year-old students and exploring the effect of applying E-learning units on their frequency. According to the Curriculum Framework, the basics of states of matter are taught within the subject My environment in the 2nd grade (age 7–8). In the 5th grade (age 10–11) within *Science*, the states of matter are taught again, including phase changes. Within physics in the 7th grade (age 12–13), students are acquainted with the notion of atoms and molecules. Within chemistry in the 8th grade (age 13–14), students learn more deeply about the structure and states of matter, and then about pure substances and mixtures. After examining the corresponding literature, the following research questions are formulated:

1. What misconceptions about structure and states of matter do students have when entering the 8th grade and encountering chemistry as a school subject?
2. Does the teaching approach in 8th grade with E-learning units affect the occurrence of misconceptions about structure and states of matter?
3. Does the teaching approach in 8th grade with E-learning units affect the occurrence of misconceptions about pure substances and mixtures?

Educational material: E-learning units

Two E-learning units (structure and states of matter – SSM and pure substances and mixtures – PSM) were designed, based on the E-learning units from the project E-kemija*.[27,28] The tool for design and development of electronic textbooks eXecute was used. The content of the E-learning units was based on the Curriculum for Chemistry course in the 8th grade of primary school and applied in teaching relevant concepts. In E-learning units both macroscopic and submicroscopic levels of representation in chemistry were included. The symbolic level is not taught yet at this stage.

The E-learning units were composed of text, pictures, videos, animations, schemes, tables and tasks. The E-learning unit SSM contained seven sections (slides) with an average number of 157.4 words per slide; the E-learning unit PSM contained nine sections with an average number of 196.7 words per slide. In most cases, video clips and pictures represent the

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* http://www.kii3.ntf.uni-lj.si/e-kemija/. The result of E-kemija project are 125 E-units designed to enable the acquisition of basic knowledge of chemistry, deepening of knowledge and checking of understanding. E-units are mainly intended for independent learning, they are always available to students, so they can look at each one as many times as they want. The project was created with the financial support of the Ministry of Education and Sports of the Republic of Slovenia and the European Social Fund. Authors of the E-learning units: Bojana Boh, Iztok Devetak, Danica Dolničar, Saša A. Glažar, Andrej Godec, Samo Jamšek, Vida Mesec, Brane Pajk, Blaž Repe, Irena Sajovic, Matej Urbančič, Margareta Vrtačnik, Katarina Wissiak Grm, and Boris Zmazek.

observable (macroscopic) level. Simple animations and drawings were used for submicroscopic representations (*e.g.*, the representation of the arrangement and movement of the particles (SSM) and the difference between pure substances and mixtures (PSM)).

Tasks were incorporated into most sections and at the end of both E-learning units. Their role was to keep students' attention during learning and to give them feedback at the end of each section. No data were collected at this point.

Design of the study

The study was quasi-experimental by its design. Students were divided into one control (CG) and two experimental groups: experimental group 1 (EG1), where the teacher-centred approach at school was followed by working on E-learning material at home, and experimental group 2 (EG2), where the E-learning units were implemented at school only. Groups were equal in their previous knowledge of the relevant concepts; this fact was examined and confirmed with the pretest at the end of 7^{th} grade. Two teaching units from the Curriculum for 8^{th}-grade chemistry were selected: Structure and states of matter (SSM) and Pure substances and mixtures (PSM). When identifying answers as misconceptions, the following criterion[29,30] was used: Incorrect answers on multiple-choice items with the occurrence of 20 % and higher are defined as misconceptions.

Participants

Participants were students from four schools located in the urban area of Sarajevo, Bosnia and Herzegovina. Permission for research was granted by the principals, teachers and students' parents from every school.

The pre-test was administered in the first phase to a total number of 191 7^{th} grade students. Some students dropped out from the sample for different reasons (change of school, inconsistency in writing their names/codes, absence from the classroom); therefore, in the second phase (next school year, 8^{th} grade), 111 students participated (Table I).

TABLE I. Participants of the study

Group	Number of participants	
	Teaching unit SSM	Teaching unit PSM
CG	33	34
EG1	39	38
EG2	39	41

Instruments and procedures

The pre-test of knowledge was administered to students within physics class in the 7^{th} grade. We were interested in students' knowledge of science content after the 7^{th} grade, which is the basis for learning new content in the 8^{th} grade.

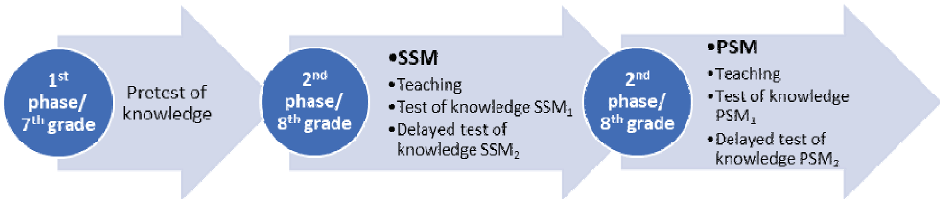
Based on the results of the pretest, students were divided into three groups.

- The experimental group 1 (EG1) was formed to introduce E-learning units as homework material after the usual teaching (teacher-centred approach) at school. EG1 students received E-learning units as homework material on compact discs (CDs) to work on them at home. All students reported that they had personal computers or laptops at home.
- In the experimental group 2 (EG2), students were learning using the E-learning units in the chemistry classroom under the supervision of a chemistry teacher and a researcher. Laptops were provided for each student in this group.

- The control group (CG) was taught traditionally, which in these schools implies teacher-centred approach. One of the researchers was present to ensure that the crucial concepts addressed in the E-learning units were also taught by the teacher in the control group.

The Levene's test of homogeneity of variances indicated that the variances are not homogeneous (F (2, 138) = 7.629, p = 0.001), so the Welch test was chosen to test the difference between the groups. It did not result in a statistically significant difference between the control (CG) and experimental (EG1 and EG2) groups on the pretest of knowledge (F (2, 83.8) = 1.058, p = 0.352). Cronbach's alpha for the pretest was α = 0.596 and it was considered as acceptable[31] for the purpose of this research*.

After ensuring that students in all groups do not differ significantly with respect to their previous knowledge, the teaching strategies which include E-learning were applied in the experimental groups, and the teacher-centred approach was used in the control group. Teaching process was implemented at schools and lasted for one teaching hour (45 min) per teaching unit. After teaching, the students' knowledge was examined using the tests of knowledge, both applied as immediate and delayed post-tests (Scheme 1).



Scheme 1. Research methodology (1st phase: pre-test of knowledge; 2nd phase: Structure and states of matter (SSM) and pure substances and mixtures (PSM).

One week after teaching structure and states of matter (SSM), the administration of the corresponding tests of knowledge (SSM_1) followed in all three groups. Approximately three months after teaching, repeated post-tests of knowledge (SSM_2) were administered to obtain insight into the retention of students' knowledge regarding the concepts taught. The same procedure was carried out with Pure substances and mixtures (PSM) teaching unit.

The reliability analysis resulted in Cronbach's alpha α = 0.711 for SSM_1 and 0.529 for SSM_2, and it is considered as acceptable even though it is relatively low in the case of SSM_2. Also, acceptable values of Cronbach's alpha were noted for PSM_1 (α = 0.734) and for PSM_2 (α = 0.704).

The sources for the construction of tests of knowledge included content of E-learning units (also taught in CG using teacher-centred approach). Incorrect options (distracters) in the items were derived from actual student alternative conceptions gathered from the literature. A pilot study was conducted one year earlier, and the tests were given to chemistry teachers prior to the application for a review, as well as to two university professors of Methodology of chemistry education.

In addition, validity was examined by conducting the analysis of correlation of each item with the total score on the test, and this resulted in statistically significant correlation for most of the items to the total score in each group of students.

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*Cronbach's alpha is recommended to be higher than or equal to 0.7 – some researchers accept 0.6 (van Griethuijsen, van Eijck & Haste, 2014) to satisfy the internal consistency of the test.

RESULTS AND DISCUSSION

The pre-test of knowledge was administered after the corresponding teaching unit regarding atoms and molecules had been taught at the end of the 7th grade within physics class. Distractor analysis of the seven multiple-choice items was performed. Incorrect answers which indicate the existence of misconception,[32] sorted by frequency in decreasing order are presented in Table II.

TABLE II. Misconceptions – pre-test (N = 191)

No.	Misconception	Frequency, %
M1	Freezing/melting/evaporation can shrink water molecules.	45.1
M2	Bubbles that occur when water is heated are made of heat.	42.9
M3	When water evaporates, it splits into hydrogen and oxygen.	41.9
M4	We cannot obtain liquid water from water vapour since it has changed.	24.1
M5	Bubbles that occur when water is heated are made of gaseous hydrogen and oxygen.	22.0
M6	If a leaflet was made from a piece of gold, its atoms became straightened.	20.9
M7	We cannot obtain liquid water from water vapour since it disappeared.	20.4

The pre-test of knowledge revealed certain misconceptions regarding the structure and states of matter that students possessed prior to the instruction: 1) Misconceptions related to the changes in states of matter: M1, M2, M3, M4, M5, M7 and 2) misconceptions resulting from assigning the macroscopic properties to the particles: M6. Same misconceptions originate from students' everyday experiences to explain the changes surrounding them; some of them are formed long before students entered school. These concepts are more thoroughly taught later on in 8th grade within Chemistry.

The structure and states of matter (SSM) test of knowledge was administered one week after teaching (SSM_1) and three months after teaching as a delayed test (SSM_2). Incorrect answers on five multiple-choice and one completion items with a frequency (f) of 20 % or higher in any of the groups on SSM_1 and/or SSM_2 are represented in Table S-I (Supplementary material to this paper), sorted by frequency in decreasing order. The proportions of students who have misconceptions as reported in Table S-I were examined using Pearson chi-square test.

Misconceptions regarding SSM can be classified as: 1) misconceptions about the arrangement and movement of particles in solids (M1 and M3); 2) the size of particles (M2, M4, M6 and M7); 3) the effect of freezing and condensation on the size of the molecule (M8, M10); 4) the existence of different particles in the same substance in different states of matter (M9); 5) the volume of a liquid can easily change (M5).

The most frequent misconceptions in all groups on both SSM_1 and SSM_2 were about the arrangement and movement of particles in solid substances (M1 and M3). The percentages of M1 and M3 for EG2 on both tests were lowest; on SSM_2, the difference in favour of EG2 for M1 was statistically significant. The source of these misconceptions could be the attribution of macroscopic properties to the submicroscopic particles. It was evident from several animations in the E-learning unit SSM that the particles in ice vibrate, but students probably did not pay enough attention or did not transfer this knowledge to all substances in the solid state.

Misconceptions regarding the size of molecules (M2, M4 and M7) were also frequent on both immediate and delayed post-test, with the lowest percentages in EG2. On SSM_2 the difference in percentages in favor of EG1 and EG2 compared to CG for misconception M2 was statistically significant. Some studies also reported students' misconceptions regarding the size of atoms.[12,32] Research also showed that in comparison to the macroscopic level of representation, students' estimates of submicroscopic spatial sizes are less precise.[33] The unobservable nanoscale is hard to conceptualize even for older students,[34] which suggests that this concept should be addressed more thoroughly in the teaching process. There is the potential of E-learning units in teaching this concept, as the findings of this study showed that, even if the misconceptions regarding the size of the particles exist in EG2 and in EG1, the percentages are lower than in CG, and in one case (M2) the difference was statistically significant.

Misconceptions about freezing (M6, M8) and condensation (M10) affecting the size of the molecules did not reach the threshold of 20 % in EG2 either on SSM_1 or SSM_2. In the case of CG, the threshold was reached for M6 on both SSM_1 and SSM_2, and M10 on SSM_2; in EG1 for M6 and M8 on SSM_1 and M10 on SSM_2. Misconceptions related to macroscopic changes affecting the size or shape of the particles are reported in a significant body of research.[15,16,35]

Different states of the same substance contain different particles (M9) is a misconception found in EG1 on the immediate post-test and in CG on the delayed post-test. Some research studies also reported comparable findings[17,18,36] suggesting that teaching about mixtures, as well as about elements and compounds, needs to include particle representations.[22]

When considering the percentages of misconceptions on SSM_1, the lower occurrences of misconceptions of EG2 students were noted, compared to CG and EG1, but the Pearson chi-square test did not indicate a statistically significant difference between the groups.

In the case of SSM_2, statistical analysis confirmed that EG2 has a significantly lower percentage of two misconceptions: M6 (particles in water vapor are smaller than the particles in ice), $p = 0.023$; M10 (freezing affects the size of a molecule), $p = 0.037$). When considering CG, this group has a significantly higher percentage for one misconception: M2 (the size of a plant cell is on the nano (1–100 nm) level), $p = 0.048$). EG1 also has significantly higher percentage for one misconception: M1 (Particles in solids are equally distributed and do not move), $p = 0.035$)*.[6]

Summarizing the above, the most common misconceptions on the structure of matter originate in transferring the macroscopic observations into the submicroscopic level and in misinterpretation of the size of particles. E-learning material can help in resolving these misconceptions by including animations of submicroscopic processes, but teachers' support is also required in explaining the processes and emphasizing the facts that distinguish submicroscopic processes from macroscopic observations.

Students' misconceptions about pure substances and mixtures

Indicators of the misconceptions about Pure substances and mixtures were also incorrect answers on seven multiple-choice and one completion items with a frequency of 20 % or higher in any of the groups. They are presented in Table S-II (Supplementary material), arranged by decreasing frequency. The test of knowledge was also administered twice: one week after teaching (PSM_1) and three months after teaching (PSM_2).

Misconceptions regarding PSM can be classified as:

Misconceptions about properties of pure substances in mixtures (M5, M10); they have also been reported in earlier research.[22,38,39]

Misconceptions about the differences between pure substances and mixtures from everyday life (M2, M4, M6, M8, M9 and M11) are also noted.[38,40–42] They originate in the everyday experience where some substances are referred to as pure (such as air, M8), and the perception of something natural (such as milk, M4) being pure. At the same time, some manufactured processed material is perceived as being a mixture.

Misconceptions about the composition of air and interchanging the notion of air with oxygen (M1, M2, M3, M8) were also reported in the literature.[39,43–45]

The Pearson chi-squared analysis for PSM_1 indicated that students in CG have significantly higher percentages for the misconception M1 ($p = 0.010$), students in EG1 for the misconception M4 ($p = 0.008$), while EG2 students have significantly lower percentages for misconceptions M1 ($p = 0.010$), M6 ($p = 0.003$) and M10 ($p = 0.039$). The analysis of percentages of misconceptions noted on PSM_2 indicated that EG2 students have a statistically significant lower percentage of the misconception M3 (oxygen in the air and pure oxygen have different properties, $p = 0.0001$), while EG1 students have a higher percentage than expected*.[37]

* According to the adjusted residuals generated in SPSS, higher than 1.96, which can be used to point to the groups that cause the differences.

The changes in percentages on the delayed tests (SSM_2 and PSM_2) can be attributed to the teaching process and the role of the teacher. During the three months between the tests, teachers were teaching their usual way, which implies teacher-cantred approach without E-learning or using multimedia-based teaching resources. The fact that misconceptions are noted in both experimental groups EG1 and EG2 on delayed test of knowledge could originate from the absence of E--learning resources. During this period, students were not exposed to E-learning material. Since SSM_1 and PSM_1 resulted in lower frequency of misconceptions of students in experimental groups, it is reasonable to hypothesize that more frequent use of E-learning material could result in better retention of knowledge and fewer misconceptions.

The incidence of misconceptions is higher regarding SSM than PSM in every group on both immediate and delayed tests of knowledge. The reason might be that students already possess certain knowledge (and misconceptions) regarding the states of matter (the effect of previously acquired misconceptions). Pure substances and mixtures (in the chemical terms) are new concepts for them.

CONCLUSIONS AND IMPLICATIONS

Two approaches to teaching the concepts of structure and states of matter, pure substances and mixtures using E-learning were applied. Effectiveness of E--learning approaches on the occurrence of misconceptions was explored, compared to the usual teacher-centred approach. One E-learning approach included the usual teacher-centred teaching in the classroom, supplemented by E-learning units as homework. The other E-learning approach was characterised by the application of E-learning units at school during chemistry classes, using laptop computers. The control group students were taught with teacher-centred teaching. With this in mind, the following research questions were examined:

1. What misconceptions about structure and states of matter do students have when entering the 8th grade and encountering chemistry as a school subject?

The insight into students' previous knowledge on the subject matter indicated that students have certain incorrect views. Misconceptions arising from assigning macroscopic properties to the submicroscopic particles were observed (physical changes affect the size of the particles, the lack of movement of particles in solids). The data gathered indicated that students have incorrect views about evaporation, believing that: 1) water splits into hydrogen and oxygen, 2) bubbles formed when water is heated are made of heat or 3) gaseous hydrogen and oxygen and 4) evaporation may shrink water molecules.

2. Does the teaching approach with E-learning units affect the frequency of misconceptions about structure and states of matter?

E-learning approach in school settings (EG2) resulted in fewer misconceptions on SSM_1 (6), compared to the control group – CG (7) and the application of

E-learning as homework material – EG1 (9). Findings pointed to the fact that the teaching applied in EG1 (teacher-centred approach at school and E-learning units at home) is less appropriate than E-learning at school (EG2) or teacher-centred approach at school only (CG). Also, the same misconceptions in EG2 (6) were noted on SSM_2. The delayed test (SSM_2) resulted in higher number of misconceptions in CG compared to SSM_1 (7 on SSM_1 and 9 on SSM_2), and in lower number of misconceptions in EG1 (9 on SSM_1 and 7 on SSM_2).

However, some misconceptions related to transferring the macroscopic properties to the submicroscopic level occur in every group (*e.g.*, particles do not move in a solid state, solidification causes particles to stop moving). These misconceptions result in lower percentages in EG2 compared to EG1 and CG, but the difference was not statistically significant. It is evident that they are rather resistant and are not significantly affected by the E-learning approaches (especially in EG1) compared to traditional teacher-centred approach. The reason might lie in the role of the teacher who moderated the learning process in EG2 at school, as the students paid too little attention to the animations of the distribution of particles in solids, which show that the particles vibrate.

Misconceptions regarding the perception of the size of particles also occur in every group (44–45 % of students in every group place plant cell on the nano level, but a lower percentage of EG2 students (26.8 %) place the particles in table salt at the micro (1–100 μm) level compared to EG1 (41.7 %) and CG (45.8 %). This fact points to the potential of representing the size of particles in E-units. It also suggests that the size of particles should be addressed more thoroughly in traditional teaching as well as in E-learning units. There was the positive effect of the particles representation in E-learning units, evident through the lower percentage of these misconceptions in EG2. However, this is not the fact for EG1. This points to the importance of the E-learning material moderated by the teacher, and the synergy of E-units with the teachers' explanation, since the size of the particles is abstract concept to the students if explained by the teacher only.

3. Does the teaching approach with E-learning units affect the frequency of misconceptions about pure substances and mixtures?

Misconceptions occurring in EG2 resulted in lower percentages for concepts of pure substances and mixtures: two misconceptions (M2 and M3) on PSM_1 and two misconceptions (M1 and M4) on PSM_2, comparing to SSM teaching unit (six misconceptions (M1–M5, M7) on both SSM_1 and SSM_2). The potential cause might be the fact that concepts of pure substances and mixtures are rather new for students from the chemical point of view, while they have certain knowledge (and pre-conceptions) on structure and states of matter from everyday life and earlier schooling and/or everyday life. It is evident that for these concepts, E-learning approaches have made significant difference as they resulted in fewer misconceptions than the traditional teaching approach. Moreover, the occurrence of misconceptions regarding PSM in CG is higher (four on PSM_1: M1, M2, M4, M10), three on PSM_2: M1, M2, M3) than in the EG2 (two on PSM_1: M2, M3, two on PSM_2: M1, M4); in the case of EG1, the occurrence is also higher (nine on PSM_1, four on PSM_2). Rather high number of misconceptions occurring in EG1 points to the conclusion that the learning process with E-units needs to be moderated and monitored by the teacher. Here, four misconceptions rather resistant to the teaching approach could be selected: three of them (M1, M2, M3), appearing on PSM_2 in EG2 and on both PSM_1 and PSM_2 in EG1 and CG are related to the misconceptions related to the air (its composition, properties of oxygen in air, interchanging the notion of air and oxygen). M4 appears in all groups once, either on PSM_1 or on PSM_2, and is related to the belief that milk is a pure substance. These findings favour the application of E-learning material in school settings compared to its application at home and with the teacher-centred approach.

The main prerequisite for E-learning in the educational process is adequate IT equipment, often limited to a few personal computers in the IT classroom. It might also require additional training for teachers, depending on their current knowledge about IT. Nevertheless, the cooperation between IT and chemistry teachers may result in the wider application of the E-learning units in school settings.

Results suggest that E-learning material that integrates macroscopic and submicroscopic levels of representation has the potential to teach fundamental chemical concepts when applied in the classroom under the teachers' supervision (EG2 approach). It enables students to learn more comprehensively, to build conceptual understanding, and therefore to reduce the occurrence of misconceptions. The occurrence of misconceptions in EG1 (students who learned using E-learning material at home after the teacher-centred approach) is rather high, which indicates the need for the teacher to guide students during E-learning. This emphasizes the important role of the teacher in teaching fundamental chemical concepts that can be supported using E-learning material. Although EG1 students were taught by the teacher (teacher-centred approach), and the use of E-learning material followed at home, it is evident that teaching by the teacher should be combined with E-learning material, instead of applying the material later.

Further research could include a more thorough study on the application of E-learning units for learning at home, with online access to the E-learning units where the teacher could track students' activity and guide them through the learning process. This approach might have greater potential than the same material provided on a CD.

SUPPLEMENTARY MATERIAL

Additional data and information are available electronically at the pages of journal website: https://www.shd-pub.org.rs/index.php/JSCS/article/view/11965, or from the corresponding author on request.

ИЗВОД

ЕФЕКТИ Е-УЧЕЊА НА ЗАБЛУДЕ УЧЕНИКА УЗРАСТА 13–14 ГОДИНА О НЕКИМ ОСНОВНИМ ХЕМИЈСКИМ ПОЈМОВИМА

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Заблуде ученика у области природних наука могу довести до низа тешкоћа у учењу ако наставник не изабере одговарајуће стратегије учења којима ће се смањити њихова учесталост. У овом раду истражене су заблуде ученика узраста 13–14 година о структури и агрегатном стању супстанци, о чистим супстанцама и смешама. Испитана је учесталост тих заблуда када се примени стратегија наставе са материјалом за Е-учење. Истраживање је изведено са ученицима 7. и 8. разреда у градским школама у Босни и Херцеговини. Добијени резултати су указали на заблуде ученика настале трансфером макроскопских посматрања на субмикроскопски ниво и погрешном интерпретацијом величине честица. Мањи проценат заблуда био је групи ученика који су користили Е-наставни материјал у школи у односу на контролну групу ученика и групу ученика који су истом материјалу за Е-учење приступали од куће. То указује да би стратегија Е-учења могла допринети бољим резултатима учења ако би се више примењивала у школама. Ова студија има за циљ да усмери пажњу наставника ка примени Е-учења у настави хемије како би ученици стекли научно прихватљива знања, а појава заблуда се смањила.

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