

The Effect of e-Learning Strategy at Primary School Level on Understanding Structure and States of Matter

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ABSTRACT

E-learning strategies for the teaching unit Structure and States of Matter were developed. Students' achievements and the percentages of misconceptions were compared between experimental groups taught using web-based learning material (WBLM) used as homework after conventional teaching at school (EG1), and at school settings (EG2) with the control group (CG) taught with the teacher-centred approach. The results indicated that WBLM has potential in teaching since EG1 and EG2 students had higher achievements than CG students did on tests of knowledge. Appropriate statistical procedures were used to control the effects of students' verbal and non-verbal intelligence, as well as their prior knowledge regarding the Particulate Nature of Matter. Certain misconceptions were also revealed in all groups of students, mostly related to transferring macroscopic properties to submicroscopic particles.

Keywords: structure and states of matter, web-based learning material, students' achievements, misconception, macroscopic level, submicroscopic level

BACKGROUND

The idea behind this research stems from the difficulties regarding the understanding of the particulate nature of matter (PNM) noted at the secondary school level, and also at the university level with chemistry and physics students. These concepts are taught at the primary school level within *Physics* and *Chemistry*, so the new e-learning material *Structure and States of Matter*, containing macroscopic and submicroscopic levels of representation, was introduced at the 8th grade primary school level. The aim was to examine its effects on improving students' understanding by reducing the occurrence of misconceptions about these basic chemical concepts.

Studies on understanding chemical phenomena imply that instruction should emphasise the multilevel of their representation (Al-Balushi & Al-Harthy, 2015) in order to make prerequisites for their full understanding (Treagust, 2018). Multilevel, also called *the chemistry triplet* (Talanquer, 2011), is described by Johnstone (1982). Chemical knowledge comprises 'at least three levels', different but interconnected: macroscopic (observable), submicroscopic (molecular), and representation (symbolic) (Johnstone, 1982; as cited in Taber, 2013). In his later papers, he represented them with a simple equilateral triangle with levels at each of its vertexes (Johnstone, 1989, 1993, 2000, as cited in Taber, 2013). Johnstone (1991, as cited in Taber, 2013) also argued that chemistry teaching is not focused on a specific vertex of the triangle but placed inside it, since students are expected to manage all three levels at once. In addition to the three levels introduced by Johnstone (1982, 1993), Meijer, Bulte, and Pilot (2009) introduced the concept of the meso-level, placed between the submicroscopic and macroscopic, with particle sizes between 10^{-1} and 10^{-7} m.

Three levels of representation make chemical concepts more demanding for teaching, but their integration is a prerequisite for meaningful learning (Gabel, 2005). This implies that these abstract concepts should be presented to the students in different ways (Devetak & Glažar, 2014). Before applying various teaching strategies and activities in the classroom, it is of crucial importance that the teachers themselves understand the concepts they teach on the three levels of representation and that they easily move between them (Devetak & Glažar, 2014).

Contribution of this paper to the literature

- Web-based Learning Material created to integrate the macroscopic and submicroscopic levels of representation has potential in teaching fundamental chemical concepts.
- E-learning units have potential as a useful tool for the repetition and consolidation of knowledge acquired at school.

Knowledge and understanding of PNM are required in order to comprehend many concepts in chemistry, such as changes in state, the behaviour of gases, chemical reactions (Singer, Tal, & Wu, 2003). It is recognised as one of the fundamental concepts in science education standards, as a part of scientific literacy (National Research Council, 1996) and in many scientific research papers (e.g. Adadan, 2013; Georghiadis, 2000; Harrison & Treagust, 2002; Novak, 2005; Singer et al., 2003).

Pitjeng (2014) found that the content knowledge about PNM was disappointingly low for novice graduate students in biology and chemistry. Papageorgiou, Stamovlasis, and Johnson (2010) reported that primary school teachers held similar misconceptions as their students did before the intervention they used during an in-service training course. Firmly held misconceptions and inadequate understanding about PNM between pre-service elementary science teachers were found by Aydeniz, Bilican, and Kirbulut (2017). These findings are in accordance with the studies conducted by Ramor (1992; as cited in Pitjeng, 2014) and Lutz and Potgieter (2013; as cited in Pitjeng, 2014).

Teaching strategies in chemistry should lead towards an understanding of chemical concepts, so as to include the macroscopic, submicroscopic and symbolic levels (Johnstone, 1982, 1993). Thus, multiple representations are crucial for chemistry instruction since the changes in the nature of substances take place at the submicroscopic level, unavailable to direct observation (Gilbert & Treagust, 2009). When teaching chemical concepts, teachers mainly address and describe the macroscopic level instead of linking it to the submicroscopic (Gilbert & Treagust, 2009). In order for students to understand specific concepts (e.g., differences in structure and states of matter), the teacher should switch to the submicroscopic level that sometimes can be a significant challenge for students to understand (Stieff, Ryu, & Yip, 2013).

Studies demonstrated students' improved performance after instruction that emphasised the macro-submicro-symbolic level of representation (Gabel, 1993; Russell et al., 1997; Sanger, 2000), especially the submicroscopic level (Hinton & Nakhleh, 1999; Jaber & BouJaoude, 2012; Milenković, Segedinac, & Hrin, 2014).

The Use of Computers in the Classroom

Conceptual understanding of chemistry can be enhanced in several ways using computer-based technologies (Ardac & Akaygun, 2005). Computers enable synchronous representation on the macroscopic, submicroscopic and symbolic levels of representation (Russell et al., 1997); therefore, they can help students in making cross-interpretations between different levels.

One resource used to emphasise the submicro level of instruction is molecular-level animations, which can be effective if designed and presented carefully (Tasker & Dalton, 2006). Research conducted among 16–17-year-old students resulted in students' positive attitudes toward both student-generated and expert animations of states of matter, as well as improved understanding (Yaseen & Aubusson, 2018). Before presenting an animation, it is important to explicitly point out the key features of the displayed animation and deal with students' prior understandings (Tasker, 2016; Tasker & Dalton, 2006).

Research has shown that students do not connect their observations on a macro level with explanations on the submicro level, which leads to developing ideas on their own, mostly the wrong ones (Barke, Hazari, & Yitbarek, 2009). Submicroscopic concepts are invisible and more abstract than macroscopic, which makes them challenging and difficult to grasp (Al-Balushi, 2013; Al-Balushi, 2011; Al-Balushi & Coll, 2013; Gericke & Hagberg, 2007; Taber, 2013).

Akaygun and Jones (2013) concluded that visualisation of the particulate level can improve students' learning, especially when using computer animations of particles, which can help students to better visualise the PNM (Chang, Quintana, & Krajcik, 2010) and enhance their conceptual understanding (Ardac & Akaygun, 2004).

Computer animations and simulations of the processes at the submicro level are valuable in helping students visualise these processes (Tang & Abraham, 2016; Williamson & Abraham, 1995; Yeziarski & Birk, 2006). Dynamic visuals are favoured over static visuals (Williamson & Abraham, 1995), since more information can be displayed with dynamic visuals, such as the velocity of particle movement in phase changes (Ardac & Akaygun, 2005). However, merely providing dynamic visuals does not necessarily result in better understanding. Learners are faced with increased information-processing demands compared to static visuals (Lowe, 2003). The transitory nature of dynamic visuals may cause higher cognitive demands (Lewalter, 2003), so molecular representations often require

instructional aid not provided by technology (Kozma, 2000; Sanger, 2000). Therefore, in addition to these representations, proper instruction is needed to enhance correct understanding (Sanger, 2000).

One of the resources that showed good results when applied in the chemistry classroom at the primary school level (age 12–13) is the virtual laboratory, which enables the simultaneous presentation of the macroscopic, submicroscopic, and symbolic levels of chemical concepts. (Rizman Herga, Čagran, & Dinevski, 2016; Rizman Herga, Glažar, & Dinevski, 2015).

It is a common practice to integrate ICT into classrooms worldwide. There are certain negative aspects of the use of ICT in schools. Instead of using computers for instructional purposes and teacher-directed student use, teachers use them for administrative activities such as writing e-mails, grading, and communication with parents (Bebbel, Russell, & O'Dwyer, 2004). As discussed by Pribush (2015), the positive impact of technology on chemistry education is greater than its negative consequences. The positive and negative aspects of the integration of ICT into chemistry teaching and learning point to the need for careful designing (or selecting from the Internet) and applying these resources, since they can both enhance and hinder students' understanding.

When choosing resources from the Internet, teachers need to be careful because not all the available resources help promote understanding. Visual stimuli are not readily "inserted" into the learners' minds; they are filtered and then re-interpreted in congruence with the existing preconceptions (Eilks, Witteck, & Pietzner, 2010). According to Fuchs and Woessmann (2004), who investigated the outcomes of the PISA (Programme for International Student Assessment) testing, the mere presence of technology at home does not improve learning achievements by itself; it is even negatively related to the student performance in math and reading.

Concepts on Structure and States of Matter

Traditionally, within chemistry at the primary school level (age 12–14), three states of matter are recognised and taught: solids, liquids, and gases. Scientists have found and defined other states of matter, which have been more or less acceptable within the scientific community. In some textbooks, four states of matter are mentioned (the three usual and plasma as the fourth state); some of them mention five states (Bose-Einstein condensates in addition to the previous), while other states of matter are more or less controversial (West, 2009). Papageorgiou et al. (2010) argued that 'scientifically, there are no such things as "solids", "liquids", and "gases": there are substances and their states' (p. 631). For the purpose of this research, the three conventional states of matter – solid, liquid and gas – are considered.

It is common for students to experience difficulties in understanding solids, liquids, and gases. Direct sensory experience leads children to a naïve view of matter (Kind, 2004). The critical condition for understanding states of matter and transitions between them is the knowledge of particle theory of matter (Treagust et al., 2010). Children do not readily use abstract ideas about particles when it comes to properties of matter; it appears they rely solely on sensory information when reasoning about the matter, up to the age of around 14 years (Kind, 2004).

Children's naïve conceptions of matter have been a common issue within science education research in recent decades. A large proportion of the difficulties students experience when moving from everyday thinking to scientific thinking is regarded as the projection of properties from the macroscopic world to the particles (atoms and molecules) – to the submicroscopic level of representation (Andersson, 1990). Students tend to generate a hybrid macroparticulate model in which particles possess macroscopic properties (Nakhleh, Samarapungavan, & Saglam, 2005). This is also the case when phase changes are considered (Andersson, 1990). Garcia Franco and Taber (2009) reported that students mainly show familiarity with the particle theory of matter but limited understanding of it.

Stavy and Stachel (1985) found that difficulties that children (age 5–12) experience with classifying substances into states of matter come from the fact that they perceive the solid state as something that does not easily change its shape, so objects such as sponges are harder to perceive as being solid. They also found that children classify liquids more easily than solids, perhaps because liquids are less varied in their physical characteristics. Students often fail to understand the intrinsic motion of particles in the solid state, whereas a majority of students were able to indicate particle movement in liquids and gases (Adbo & Taber, 2009; Boz, 2006). Specific difficulties students experience with gases come from the fact that air, often used as an example, is invisible (Kind, 2004; Stavy, 1988). While children learn about solids and liquids intuitively, instruction is needed when they acquire knowledge of gases (Stavy, 1988). Students at the primary and lower secondary levels (age 12–16) rarely view air as an example of a gas. They relate gas to something harmful, but air to breathing and life (Andersson, 1990).

Findings from Slapničar, Devetak, Glažar, and Pavlin (2017) suggest that there was no significant difference between the most common misconceptions held by different age groups (12-, 14-, and 16-year-old students) regarding states of matter with respect to water and air. Certain misconceptions related to the states of matter held by primary school students are also reported by Slapničar, Tompa, Glažar, and Devetak (2018).

One of the first studies on children's conceptions about changes in states of matter (melting, evaporation, and condensation) was performed by Osborne and Cosgrove in 1983. They uncovered a number of non-scientific conceptions among children 12–17 years old. Some of them persisted even after teaching (Tytler, 2000), such as air being in the bubbles formed when water is heated.

The importance of the PNM concept in science education has been highlighted in many research studies in the past several decades (Gabel, 1993; Harrison & Treagust, 2002; Novick & Nussbaum, 1978; Nyachwaya et al., 2011; Osborne & Cosgrove, 1983; Tang & Abraham, 2016). Tang and Abraham (2016) considered this topic as one of the most difficult to learn because it includes logical operations at the level that students are not able to be in personal contact with – the level of atoms and molecules.

E-learning

E-learning is an educational strategy that has shown good results in science education. Clark and Mayer (2011) define e-learning as instruction delivered on a digital device such as a desktop or laptop computer or a mobile device that is intended to support learning. They differentiated two forms of e-learning: *asynchronous* (self-learning available upon demand) and *synchronous* (instructor-led e-learning presented at a fixed time).

Effects of e-learning include an increase in students' motivation (especially for low-achieving students), engagement and attendance. Some meta-analyses have found that learning results are to some degree enhanced with a combined approach: e-learning and face-to-face (Means, Toyama, Murphy, Bakia, & Jones, 2009; Roblyer & Doering, 2009; as cited in Olson et al., 2011).

The important assumption of the constructivist learning theory is that the learner acquires knowledge by integrating new information with the existing; in this process, the key element is learners' active participation. Bodner (1986) summarized the constructivist theory in this sentence: "Knowledge is constructed in the mind of the learner" (Bodner, 1986, p. 873). According to Koohang, Riley, Smith, and Schreurs (2009, p. 91), constructivist learning theory is "a good fit for e-learning because it ensures learning among learners". Constructivism is also useful in explaining students' misconceptions in science and why they are so hard to change into scientifically accepted conceptions. The only way that an existing idea could be replaced is by constructing the new idea that better explains students' experiences (Bodner, 1986).

Ural and Ercan (2015) examined the effects of the use of web-based educational software, enriched with concept maps used to teach *Structure and Properties of Matter*, on the academic achievement of 7th-grade students in Turkey. The results of their study showed that these materials had a positive impact on students' academic achievements for three reasons: (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, as well as the fact that (3) this learning material has been designed with meaningful learning in mind – learning that requires the connection of new knowledge with the previously acquired knowledge.

Stern, Barnea, and Shauli (2008) evaluated the effect of a dynamic software simulation on the understanding of the kinetic molecular theory among 7th-grade students. Their results indicated that students in the experimental group scored significantly higher and showed an improved understanding of the differences in arrangement and motion of molecules in the three states of matter compared to the students in the control group.

The application of e-learning is not limited to primary and secondary schools. Potter and Overton (2006) designed a learning resource for chemistry and presented it to university students. The results of their study showed that students responded positively to it.

Ercan, Ural, and Özateş (2016) pointed out that students favour web-based learning because of its powerful visual form, the chance to learn at their own pace, step-by-step, according to their learning speed, and the chance to repeat the material if necessary. Their research showed that Web-Based Learning Material (WBLM) contributed to students' positive attitudes towards chemistry, which is correlated to their academic achievement. Findings from Olakanmi (2015) suggested significantly improved achievements of students who used web-based computer simulations in their learning rate regarding chemical reactions, which implies the need for the training of chemistry teachers to use such materials.

RESEARCH PROBLEM

The education system in Bosnia and Herzegovina (B&H) is a reflection of the internal organisation of the state. B&H is constituted of two entities (*Federation of Bosnia and Herzegovina* and *Republic of Srpska*) and one district (*District Brčko*). Consequently, there are three valid curricula, which are the same with regard to their structure and teaching methods. Regarding the teaching content, there are certain differences between the curricula, especially within the national groups of teaching subjects (Ibrahimović, 2015). The reform from eight-year-long to nine-year-

long primary education started in 2004, but they were not conducted at the same time and systematically in the entire country. Students now enrol primary school at the age of 6 and complete the 9th grade at the age of 15. Another current paradox of the B&H education system is *two schools under one roof*, which refer to some primary schools in the Federation of Bosnia and Herzegovina in which students are segregated by their nationality. Even though these schools have been declared to be unconstitutional, they continue to operate.

According to the *Curriculum Framework for nine-year primary school education in the Federation of Bosnia and Herzegovina*, the basics of states of matter are taught within *My environment* in the 2nd grade (age 7-8; students should 'identify different states of matter'¹). In the 5th grade (age 10-11) within *Science*, the states of matter are taught again, including phase changes ('through experiments, students should gain knowledge on the transition from one state of matter to another'²). Within *Physics* in the 7th grade (age 12-13), students learn about the structure of matter and states of matter at the submicroscopic level. Within *Chemistry* in the 8th grade (age 13-14), students learn again about the structure and states of matter at the macroscopic and submicroscopic levels, while the symbolic is introduced later.

The research on students' misconceptions, their sources and potential ways to overcome them was driven by a number of students' difficulties that were diagnosed in the written part of chemistry exams after enrolling in the university study of chemistry. Those difficulties were noted even later, at the university level (1st and 2nd year) (Gojak et al., 2012). The idea for this research came from the need for investigating whether these difficulties partially arise from primary education when students start to learn fundamental chemical concepts. The purpose of this research is to investigate the effects of e-learning on the students' understanding of the structure and states of matter on the submicro level.

Research Methodology

The study employed a quasi-experimental research approach with a non-randomized pre-test and post-test comparison group. It was performed in compliance with the relevant laws and with the parents' and school principals' permissions. Safety precautions regarding information technology equipment were taken into consideration. The study was implemented by the researcher and a cooperative 8th grade chemistry teacher who was present during the class. The data obtained from the study were dealt with by the researcher, and no one else was aware of the participants' scores. The participants' identities were kept anonymous. The language of instruction was Bosnian; therefore, all materials are presented in the Bosnian language.

Four hypotheses were set: (1) students who learn using WBLM at school will have higher achievements on immediate and delayed post-tests of knowledge than students who are taught in the traditional way with the teacher-centered approach; (2) students who will use WBLM as homework material (after the teacher-centered approach) will have higher achievements on immediate and delayed post-tests of knowledge than students who will be taught with the teacher-centered approach only; (3) students who will learn using WBLM at school will have fewer misconceptions than students who will be taught with the teacher-centered approach, and (4) students who will use WBLM as homework material will have fewer misconceptions than students who were taught with the teacher-centered approach (CG).

Procedure

The first phase included administering TK_{phys} as a pre-test of knowledge to 7th-grade students in four urban primary schools. After the summer break, the second phase of the study continued with the same students, by administering Raven's SPM and MHVS. In the introductory class, the research was presented to the experimental groups of students, including instructions for using the e-learning units on the laptop computers. Then the teaching of *Structure and States of Matter* (SSM) followed in all groups.

An e-learning unit was designed for this study, based on the e-learning units from the project E-kemija,³ using a tool for the design and development of electronic textbooks (eXecute) and delivered to students using PCs/laptops. They were developed based on the curriculum for the *Chemistry* course in 8th-grade primary school,

¹ Framework of a Curriculum for nine-year primary school education in Federation of Bosnia and Herzegovina, section 'Abilities and skills', p. 86.

² Framework of a Curriculum for nine-year primary school education in Federation of Bosnia and Herzegovina, section 'Knowledge', p. 246.

³ The authors of the e-learning units within the project E-kemija: 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. This project was implemented with the financial support of the Ministry for Education, Science and Sport of the Republic of Slovenia and European Social Fund.

Table 1. E-learning unit *Structure and States of Matter (SSM)*

Slide number	Title	Word count	Videos	Animations	Pictures	Drawings/Bookmark not defined.	Schemes/Tables	Tasks
Slide 1	Substances are made of particles	233	1	-	-	-	-	-
Slide 2	Evaporation of bromine	126	1	-	-	-	1	-
Slide 3	States of matter	198	1	3	-	-	-	-
Slide 4	States of water	115	1	-	-	3	-	1
Slide 5	Summary	167	-	-	-	3	-	4
Slide 6	Tasks	139	-	-	1	-	-	3
Slide 7	Tasks	124	-	-	-	8	-	3
Total		1102	4	3	1	14	1	11

adapted and applied in teaching relevant concepts. In designing the e-learning units, both macroscopic and submicroscopic levels of representation in chemistry were included.

The e-learning unit SSM contained seven sections (slides) with an average number of 157.4 words per slide. **Table 1** represents the number of selected elements on each slide.

Tasks were incorporated into most sections and at the end of the e-learning unit. 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.

One week after teaching, the administration of the corresponding test of knowledge (TK_{SSM1}) followed. Approximately three months after teaching, the repeated post-test of knowledge (TK_{SSM2}) was administered in order to obtain insight into the retention of students' knowledge regarding the taught concepts.

Participants of the Study

The sample consisted of 111 primary school students at the end of 7th grade (age 12–13) and at the beginning of 8th grade (age 13–14). Some students dropped out of the sample (change of school or absence from the classroom on one or more occasions). The students were divided into one control and two experimental groups.

In the experimental group 1 (EG1, N=24) e-learning units were introduced as homework material after the usual teaching (teacher-centred approach) at school. Students received material for homework on compact discs (CDs) to work on them at home. All students from EG1 reported that they had personal computers or laptops at home. In the experimental group 2 (EG2, N=39), laptops were provided for each student. This enabled students to learn using e-learning units in the chemistry classroom under the supervision of a chemistry teacher and a researcher. The role of the chemistry teacher in EG2 was to explain the procedure that students need to follow during the class, to resolve students' possible doubts and to maintain discipline in the classroom at an adequate level. The control group (CG, N=48) was taught in the traditional way, with the teacher-centred approach. The researcher was present to ensure that the crucial concepts addressed in the e-learning units were also taught by the teacher in the control group.

Teaching strategy is not the only factor that affects students' achievements. Therefore, the following variables were selected, and their effects on the achievements in tests of knowledge are taken into account when discussing the results: students' learning preferences and attitudes related to chemistry, motivation for learning, intellectual ability, and the socio-demographic status of students.

Instruments for Data Collection

Pre-test of knowledge TK_{Phys}, a paper-and-pencil test designed for the purpose of this study, contained nine objective items regarding the macroscopic and/or submicroscopic level of representation of the states of matter. This test was used to assess the understanding of relevant concepts prior to the instructional period. The sources for the construction of this test included an instrument reported in the study of Christian and Yeziarski (2012) and the Framework of Curriculum for 7th grade *Physics*. Incorrect options (distracters) in the items were derived from actual student alternative conceptions gathered from the literature. Achievements on this test were used as a basis for grouping students into control and experimental groups.

Post-test of knowledge TK_{SSM}, a paper-and-pencil test designed for the purpose of this study containing 10 items, was used to establish the effects of e-learning units on understanding concepts taught with the use of web-based learning material (WBLM). The same posttest was repeated three months after teaching in order to test the retention of students' knowledge. The items were formulated with respect to the teaching content.

Table 2. Cronbach's alpha coefficients for instruments for data collection

Instrument					
TK _{Phys}	TK _{SSM1}	TK _{SSM2}	Q _{ML}	Q _{LC}	Q _{AC}
.596	.711	.529	.988	.745	.845

Table 3. Total descriptive statistics of TK_{Phys}

Items	Max. score	M	SD	SE	C	SIQ	Mode
Σ 9	14	9.47	2.51	0.18	10	1.5	10

Legend: *M* - mean; *SD* - standard deviation; *SE* - standard error of the mean; *C* - median; *SIQ* - semi-interquartile range; *Mode* - modus

Raven's Standard Progressive Matrices (SPM) and the Mill Hill Vocabulary Scale (MHVS) were administered by trained psychologists. The aim was to assess students' intellectual ability from a non-verbal perspective (using SPM) and to measure verbal intelligence (using MHVS), as they are predictors of academic success (Flanagan, Andrews, & Genshaft, 1997, as cited in Kaya, Juntune, & Stough, 2015).

In addition, the following questionnaires were administered: *How I learn Chemistry* (Q_{LC}; Jurišević & Devetak, 2010), *Attitude towards Chemistry* (Q_{AC}; Jurišević, Vogrinc, & Glažar (2010), *Motivation for Learning* (Q_{ML}; Jurišević, 2010) and *Socio-demographic Status of Students* (Q_{SD}; adopted from TIMSS, 2007).

All instruments were piloted. The pre-test of knowledge resulted in a low value of internal consistency. The reasons for this fact could be various, such as different aspects of tested knowledge, different types of items, and a small number of items in the scale (Pallant, 2010; Tavakol & Dennick, 2011). This does not mean that the instrument needs to be discarded; so, after the revision of scoring, we decided to keep it within the main study. The test of knowledge TK_{SSM} resulted in acceptable internal consistency, only the revision of scoring was done.

The internal consistency of the test was evaluated using Cronbach's alpha coefficient.

Reliability analysis of instruments for collecting data resulted in generally acceptable values. Low alpha coefficients for TK_{Phys} and TK_{SSM2} could be explained by different types and a limited number of test items and a rather wide range of tested knowledge. It is generally desirable for instruments to have high alphas; however, Taber (2017) claims that '[...] administration of instruments genuinely testing a range of distinct knowledge facets should not be expected to give high alphas' (p. 18). According to Dall'Oglio et al. (2010), alpha value of .5 can be acceptable for instruments containing fewer than 20 items. Some other studies also found instruments with alpha lower than .6 as acceptable (Berger & Hänze, 2015; Bretz & McClary, 2014; Nehring, Nowak, zu Belzen, & Tiemann, 2015).

Based on the experiences from conducting the pilot study, an idea to explore the effect of e-learning units as homework material emerged. Therefore, two experimental groups were formed: EG1 taught with the teacher-centered approach with e-learning units as homework material, and EG2 taught using e-learning units in the classroom.

The revision of e-learning units was mainly addressed to rephrasing some sentences that appeared to be unclear to students. Instead of using personal computers, laptops were provided within the main study for each student in EG2 which they have been using them in the chemistry classroom. Students were able to work individually, at their own pace.

Method of Data Analysis

For creating the database and for statistical analysis, Microsoft® Excel 2007 and IBM SPSS Statistics® for Windows (Statistical Package for the Social Sciences), version 21, were used. The analysis of data was carried out using both descriptive and inferential statistics. The post-test score was subjected to analysis of variance (One-way ANOVA, Welch test, Kruskal-Wallis H test) and analysis of covariance (ANCOVA) using pre-test, Raven's SPM and MHVS scores as covariates. The ANCOVA analysis aimed to 'statistically control' for the influence of confounding variables. A p-value of less than 0.05 was considered to be statistically significant.

FINDINGS

Students' Previous Knowledge of the Relevant Science Concepts

The test of knowledge TK_{Phys} was administered to 7th-grade students, with the main aims of verifying whether the students divided into groups are equal regarding their previous knowledge, and to reveal their potential misconceptions. The total descriptive statistics for TK_{Phys} is represented in Table 3.

Table 4. Descriptive statistics and analysis of variance of students' achievements on TK_{Phys}

Groups	Max. score	M	SD	Mode (s)	Shapiro-Wilk's test		Levene's test		Welch test	
					W	p	F (2, 138)	p	F (2, 83.8)	p
CG	14	9.40	1.89	8.0 10.0	.980	.451	7.629	.001	1.058	.352
EG1		9.32	1.04	10.0	.954	.094				
EG2		9.90	2.39	10.0	.956	.099				

The mean value indicates that the average students' achievements are around 67% of the maximum score. The analysis of variance performed for students' total scores on TK_{Phys} is presented along with descriptive statistics of students' achievements in **Table 4**.

Six assumptions for the one-way ANOVA were analyzed (Laerd Statistics, 2013), and five of them were met. The assumption of normality of data was met after grouping students into control and experimental groups. Levene's test indicated that the variances are not homogeneous, so the Welch test was chosen as a statistical test, which indicated that control (CG) and experimental (EG1 and EG2) groups do not differ significantly by their achievements on the pre-test of knowledge TK_{Phys}.

Results of this pre-test showed that the students do not differentiate the macroscopic and submicroscopic levels regarding the structure of matter and that they had not developed concepts of atoms and molecules. Students know certain phenomena about states of matter from everyday experience, but they are not able to explain them at the submicro level. Previous research showed comparable findings (Kozma & Russell, 1997; Rappoport & Ashkenazi, 2008; Treagust, Chittleborough, & Mamiala, 2003). Learning submicro-macro thinking is abstract, non-observable and can be difficult for students (Gilbert & Treagust, 2009; Taber, 2001; Tsapalis, 1997). This implies that those concepts that include processes on the submicro level can be too demanding for 7th-grade students (age 12-13) if they were taught in the traditional way using teacher-centred teaching.

Motivation for Learning

There was a need to explore whether students from the control (CG) and experimental (EG1 and EG2) groups differed in their motivation to learn, their learning preferences, and their attitudes towards chemistry. For this purpose, the questionnaire Q_{ML} (Jurišević, 2010) was administered within the main study. Nineteen elements, grouped into eight thematic groups within learning motivation, were analyzed: learning interest, attributions for success, attributions for failure, self-concept, the stimulus for learning, the importance and usefulness of learning, motivational goals and perceived difficulty (Jurišević, 2010).

Statistical analysis indicates three elements (*attribution for failure - abilities* ($p = 0.029$, $\eta_p^2 = .056$), *attribution for failure - cause unknown* ($p = 0.037$, $\eta_p^2 = .052$), and *external enticement* ($p = 0.047$, $\eta_p^2 = .062$)) that resulted in a statistically significant difference between the groups. According to the benchmarks for eta squared reported by Cohen (1988, as cited in Lakens, 2013), the effect sizes are small or medium, so we can summarize that the groups of students are generally equal with respect to their motivation to learn and that the observed differences did not significantly affect their achievements on the tests of knowledge.

Students' Learning Preferences related to Chemistry

To determine students' learning preferences (styles), the social context they prefer when they learn and the types of learning items, the questionnaire Q_{LC} was administered. According to the non-parametric Kruskal-Wallis H-test, there were only two segments (out of total 18) which resulted in a statistically significant difference between the groups: students' self-concept ($p = 0.018$), and preference regarding the type of items ($p = 0.039$). We can summarise that generally there was no statistically significant difference between the control and experimental groups when considering students' learning preferences, social context or the types of tasks they prefer.

Students' Attitudes towards Chemistry

Students' self-esteem and expression of their individual interest in chemistry were examined using the questionnaire Q_{AC}. Differences between the group means for these two subscales were analysed. Both subscales resulted in comparable, medium values of mean with no statistically significant difference between groups.

Socio-demographic Characteristics of Students

The secondary analysis of TIMSS 2007 in B&H, the first and still the last TIMSS study implemented there, suggested the significant influence of some socio-demographic variables on the students' academic achievements

Table 5. Total descriptive statistics for TK_{SSM1} and TK_{SSM2}

Group		<i>M</i>	<i>SD</i>	<i>SE</i>	<i>C</i>	<i>SQR</i>	<i>Mode</i>	<i>X_{min}</i>	<i>X_{max}</i>	<i>s²</i>
CG (n = 48)	TK _{SSM1}	7.41	2.57	.37	8.38	1.94	8.5	1.0	11.5	6.59
	TK _{SSM2}	8.87	2.07	.30	9.50	1.35	9.5	4.0	12.25	4.27
EG1 (n = 24)	TK _{SSM1}	8.79	3.03	.62	9.50	2.63	4.0	4.0	13.5	9.19
	TK _{SSM2}	9.77	1.69	.34	9.75	1.00	9.3	6.0	13.5	2.85
EG2 (n = 39)	TK _{SSM1}	10.05	2.30	.37	10.5	0.75	11.0	2.0	13.0	5.30
	TK _{SSM2}	9.90	2.11	.34	10.5	1.38	12.0	3.25	12.0	4.43

Legend: *M* – mean, *SD* – standard deviation, ΔM – difference between means, *SE* – standard error of mean, *C* – median, *SQR* – semiinterquartile range, *Mode* – modus; *X_{min}* - minimum score on the test, *X_{max}* – maximum score on the test, *s²* - variance, Kurt - coefficient of kurtosis, Skew – coefficient of skewness

Table 6. Analysis of variance for TK_{SSM1} and TK_{SSM2}

Test of knowledge	Group	<i>M</i>	<i>SD</i>	<i>SE</i>	Levene's test		Analysis of variance			
					<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>
TK _{SSM1}	CG	7.41	2.57	.37	4.644	.012	12.610 ^a	.0001	8.735 ^c	.0001
	EG1	8.79	3.03	.62						
	EG2	10.05	2.30	.37						
TK _{SSM2}	CG	8.87	2.07	.30	.817	.444	3.275 ^b	.042		
	EG1	9.77	1.69	.34						
	EG2	9.90	2.11	.34						

^a – Welch test; ^b – One-way ANOVA; ^c – Repeated Measures ANOVA

in mathematics and science (Skelić & Alić, 2009). The questionnaire regarding the socio-demographic status of students from TIMSS was adapted and implemented in this research. Here it should be noted that all students attend schools in the urban area. Seven of 30 total variables resulted in statistically significant differences between the groups. These variables mostly refer to the relationship of students with parents considering their homework. However, there is no visible pattern that would segregate students of any group from the other two; so, we can assume that these differences did not affect students' achievements on the tests of knowledge.

Students' Knowledge of Structure and States of Matter (SSM)

Within this teaching unit, the concepts (particles as an integral part of the substances, states of matter and phase changes) were addressed in the e-learning unit and in traditional teaching. Descriptive statistics for both the tests are presented in Table 5.

The control group (CG, teacher-centred approach) resulted in the lowest average students' achievements on TK_{SSM1}, while EG2 (WBLM applied in the classroom) resulted in the highest achievements. The average achievements were higher on the delayed test (TK_{SSM2}) in CG and EG1 (WBLM as homework), still highest in EG2. Median values (*C*) were higher on TK_{SSM2} for CG and EG1 and equal for EG2.

Since TK_{SSM} was administered twice, data were analysed using the Repeated Measures (RM) ANOVA (Table 6). In addition, in order to evaluate the effectiveness of the teaching strategy, the one-way analysis of variance has been performed for each set of data (TK_{SSM1} and TK_{SSM2}). The test of between-subjects effects (groups CG, EG1 and EG2) indicated that the effect of the application of WBLM on students' achievements on the tests of knowledge was statistically significant ($\eta_p^2 = .139$). Multiple comparisons indicated that the statistically significant mean difference is between CG and EG2 ($\Delta M = 1.83, p = .000$).

The Welch test for TK_{SSM1} resulted in a statistically significant difference between the groups. The Games-Howell posthoc test pointed to the difference between CG and EG2 ($\Delta M = 2.54, p = .000$). The one-way ANOVA carried out for TK_{SSM2} also resulted in a statistically significant difference between the groups. However, the Scheffe posthoc test did not result in a statistically significant difference between the means. The independent sample t-test was then used to compare the means between each of the groups and resulted in the statistically significant difference between CG and EG2 ($t(85) = -2.287, p = .025$) in favour of EG2.

Analysis of Covariance (ANCOVA)

Analysis of covariance (ANCOVA) was performed, using Raven's SPM, MHVS, and students' achievements on pre-test TK_{Phys}, as covariates. All covariates were analysed individually.

Two assumptions for ANCOVA were not met (homogeneity of variance and normality of data). Covariates SPM, MHVS, and TK_{Phys} did not meet the assumption of normality. Having these limitations in mind, this analysis

Table 7. Results of one-way ANCOVA

Test of knowledge	Covariate	One-way ANCOVA				Effect of covariate		
		F	df1	df2	p	η_p^2	F	p
TK _{SSM1}	SPM	11.139	2	107	.0001	.172	.006	.939
	MHVS	9.850	2	101	.0001	.163	51.339	.0001
	TK _{Phys}	8.890	2	107	.0001	.142	18.216	.0001
TK _{SSM2}	SPM	3.227	2	107	.044	.057	1.014	.316
	MHVS	1.279	2	101	.283	.025	59.580	.0001
	TK _{Phys}	1.881	2	107	.157	.034	23.262	.0001

was conducted but taking into consideration that it is not as informative as it would be if these assumptions were met. The results of the analysis of covariance are presented in [Table 7](#).

The effect of SPM as a covariate was not significant in predicting the students' achievements. The role of MHVS as a covariate was statistically significant with a considerably high effect size. Still, after controlling the effect of MHVS, the difference between the groups for achievements on TK_{SSM1} (in favour of EG2 over EG1 and CG) was statistically significant. When taking into account the effect of TK_{Phys}, the difference was still statistically significant for TK_{SSM1} (in favour of EG2 over CG) and at the border of statistical significance ($p = .054$ when EG1 and CG were compared).

One-way ANCOVA performed for TK_{SSM2} indicated that after controlling the effects of MHVS and TK_{Phys}, the difference between the groups was not statistically significant.

Analysis of Misconceptions about *Structure and States of Matter* (SSM)

Certain misconceptions about *Structure and States of matter* occur in every group of students. The criterion for a distractor of the multiple-choice item to be selected as a misconception was the occurrence of 20% and higher, as reported in Dhindsa and Treagust (2009) and Milenković, Hrin, Segedinac, and Horvat (2016), taken from Gilbert (1977). Students in EG2 have lower or comparable occurrences of misconceptions on TK_{SSM1} comparing to CG and EG1, but the difference was not statistically significant ($p > .05$). Misconceptions noted are related to the opinion that particles do not move in a solid state of matter, and to the size of particles at the micro and nano levels, which suggest that these concepts should be addressed more thoroughly.

The chi-square test for the occurrence of misconceptions on TK_{SSM2} resulted in a statistically significant difference between the groups. The adjusted residuals suggest that EG2 has a statistically significant lower percentage for two misconceptions related to macroscopic properties transferred to the submicroscopic world ($p = .037$; $p = .035$). CG has a higher percentage of the misconceptions also related to the transferring macroscopic properties to the submicroscopic level ($p = .023$) and to the size of particles at nano-level ($p = .048$). EG1 students have higher percentages of the misconception related to the transferring macroscopic properties to the submicroscopic level ($p = .035$).

CONCLUSION

There were two approaches to teaching concepts in *Structure and States of Matter* using WBLM. The first approach was characterised by the usual teacher-centred teaching in the classroom and e-learning units as homework (EG1). The other approach included the application of e-learning units at school during chemistry classes, using laptop computers (EG2). The control group students were taught the usual way, with the teacher-centred approach (CG).

The control of the effects of students' prior knowledge, intellectual ability (SPM) and verbal knowledge (MHVS) has enabled us to ascertain the differences in students' achievements with respect to the teaching strategies. Total scores on the immediate and delayed post-tests of knowledge were compared using appropriate statistical procedures. Students who learned using WBLM at school had statistically significant higher achievements on the post-test of knowledge administered one week after teaching than control group students. Results indicated that the retention of knowledge was also higher in EG2 since these students scored higher than CG students on delayed post-test three months after teaching, which confirms the first hypothesis.

Students who were learning using WBLM at home (EG1) also scored higher than CG students did, which is in accordance with our second hypothesis. When considering the test of knowledge applied one week after the teaching, these differences were at the edge of statistical significance after controlling the effect of TK_{Phys}, but not significant in the case of delayed post-test after controlling both MHVS and TK_{Phys}.

The data indicated that students have certain incorrect views about SSM arising from assigning macroscopic properties to submicroscopic particles, and students' perception of the size of the particles. The percentages of

students possessing these misconceptions are lower in EG2 than in CG and EG1, and the difference was statistically significant. These results have validated our third hypothesis. The fact that EG1 students possessed certain misconceptions in higher percentage (fourth hypothesis) we can attribute to one of the limitations of the study since we were not able to determine if EG1 students were learning using WBLM at home.

Some of the limitations of the research were revealed within the pilot study, such as limited availability of personal computers in school settings which was resolved by providing laptops to EG2 students. Furthermore, the researcher was not able to be present in each classroom for administering each instrument. On some occasions, the administration depended on the teacher. Some teachers, however, were not fully cooperative, which in turn resulted in the dismissal of some copies of the instruments as unreliable.

The teacher-centered approach is common in our schools and both teachers and students are used to it, which makes the change towards more learner-centered teaching quite demanding. However, our mission is a learner-centered school environment and this study is a step toward this goal.

Part of limitations refers to the sample itself. There was a certain number of EG1 students who reported they could not access the teaching content on compact discs, due to a "computer virus" or that "there was nothing" on CD. We needed to discard the data gathered from these students too. Another important aspect was teachers' scepticism about the application of e-learning units. They believe that in addition to the e-learning units, the teacher needs to give some input too, so students would have material for learning in their notebooks.

It should be highlighted that the students in EG2 were learning in the classroom and their work on e-learning units was controlled by the teacher and researcher who were monitoring their progress. The EG1 students were working at home, and there was no mechanism to control if they worked as planned. This probably reflects on the students' achievements. Nevertheless, EG1 students scored higher (even though not statistically significant) than students in CG on both the immediate and delayed tests. This indicates that e-learning units have potential as a useful tool for the repetition and consolidation of knowledge acquired at school.

Since e-learning units are made considering the triple nature of representing chemical concepts, these results indicate the considerable potential of e-learning units applied both in the classroom and as homework material, with the aim to promote learning with understanding.

E-learning has been reported to have benefits in teaching and learning science in many research studies, such as that of Faulconer, Griffith, Wood, Acharyya, and Roberts (2018); Anđelković, Anđelković and Nikolić (2015); Awad (2014); Odhiambo (2010); Frailich, Kesner and Hofstein (2007). The results of this research are congruent with the published results when considering the effectiveness of the teaching strategy including WBLM applied in the classroom.

A more thorough study on the implementation of e-learning units as homework assignments could be included in further studies. Providing online access to the e-learning units would be more convenient for students than using CDs; it can also be more easily tracked. This provides an opportunity to find out whether the students actually tried to access the content of e-learning units. E-learning units could be redesigned to be supported by smartphones and tablets.

The study could be deepened by including schools from rural regions. Potential variations between students in sociodemographic status might affect their achievements. It is also possible to investigate the impact of applying e-learning units on students' motivation to study chemistry, their attitudes towards chemistry and their learning preferences.

Moreover, Osborne, Simon, and Collins (2003) have compiled a significant number of studies indicating that the role of the teacher and his/ her attitudes is very important in the teaching process. Since certain teachers' scepticism regarding the application of e-learning units was noted, it is possible to expand the research by exploring the influence of teachers' attitudes.

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