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The influence of active learning and submicrorepresentations on 14-year-old students' understanding of the alkaline earth metal concepts

KATARINA SENTA WISSIAK GRM* and IZTOK DEVETAK

University of Ljubljana, Faculty of Education, Kardeljeva pl. 16, 1000 Ljubljana, Slovenia

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Abstract: This study aimed to examine the impact of two different approaches on students' understanding of selected chemical concepts. The first treatment group was taught by a method comprising guided active learning demonstrations, and the second treatment group was exposed to guided active learning demonstrations with explanations at the submicroscopic level. In a control group, the selected topic was taught without guided active learning demonstrations and without explanations at the submicroscopic level. The instruments used in this research included the test of logical thinking (TOLT), knowledge pre-test (KPT), two achievement tests (AT-1 and AT-2) and a questionnaire for students. One hundred and seventy-one students (average age 13.9 years) participated in the study. The results indicate that both approaches (*i.e.*, guided active learning demonstrations and guided active learning demonstrations with explanations at submicroscopic level) are more effective than only symbolic teaching. It can be concluded from the results that students' knowledge, obtained by either method that includes guided active learning, is retained in the students' long-term memory. Some suggestions for implications for the primary science curriculum are also discussed.

Keywords: chemistry; lower secondary school; cooperative learning; student centred-learning; triple nature of chemical concepts.

INTRODUCTION

The teaching and learning of chemistry have undergone many changes, and different strategies have been introduced in recent years to reduce students' misconceptions. Research papers published internationally discuss the more or less positive effects of educational strategies using the three levels of chemical representations (*i.e.*, macro, submicro and symbolic level).[1–11]

* Corresponding author. E-mail: katarina.wissiak@pef.uni-lj.si
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Students' should be engaged in a more active role during teaching and learning in the classroom, where they are more or less guided during the learning process.[11] Active learning strategies, such as POGIL developed in the US or the PARSEL, PROFILES and GALC strategies introduced in Europe emphasize students' central role in their learning. In this context, teachers are leaders of the learning process, and they do not have a central role in teaching.[12,13]

The main purpose of the present research is to investigate the effect of two different teaching approaches: 1) a guided active learning strategy with macroscopic demonstration and 2) a guided active learning strategy including macroscopic demonstration supported by the sub-microlevel explanations of selected chemical concepts regarding alkaline earth metals.

Theoretical background

For years, chemistry education researchers have been exploring how three levels of chemical representations help students develop the conceptual understanding of chemical phenomena.[14–23] In comparison with the triangle of three levels of chemical representations, which was introduced by Alex Johnstone (1982), other authors have attempted to upgrade Johnstones' model, showing different levels of connections between triple nature of chemical concepts and also attempt to put the Johnstones' triangle into the new perspective.[21,24,25] The interdependence of three levels of science concepts representations (ITLS) model shows different levels of the interdependence of chemical representations in connection with the visualization method used in the science classroom and mental models of chemical phenomena that this model helps students to develop (Fig. 1).[25]

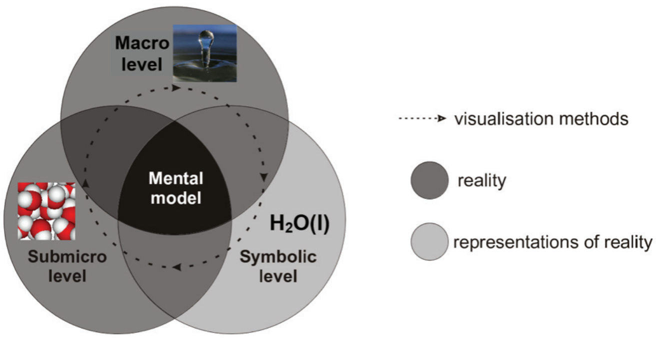

Fig. 1. Model representing interdependence of three levels of science concepts – ITLS model.[25]

The ITLS model connects the concrete (*i.e.*, sensory, experimental, *etc.*) macro level with the abstract (*i.e.*, particulate) sub-microlevel and abstract (mathematical, diagrams, pictures, chemical symbols and equations, *etc.*) symbolic levels. Macro- and sub-microlevels are present in natural phenomena. The pre-

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sentations of the sub-microlevel, including the particulate model, are mental constructs to explain and predict macro phenomena. The symbolic one is the simple representation of it and helps people communicate about the phenomena and conduct further research. All three levels should cover and supplement each other in a specific way so that adequate mental models of the natural phenomena should be developed in students' long-term memory. These mental models should be as far as possible understandable for students, without misconceptions. For these mental models to be created; students should be actively engaged in different educational strategies. These strategies should incorporate appropriate visualization elements to illustrate the abstract submicrolevel of natural phenomena (*i.e.*, submicrorepresentations, physical models, *etc.*) Understanding of the phenomena is established when all three levels of the concepts representations are adequately integrated into students' long-term memory, where the concept structure can influence students' chemical (scientific) literacy.[9,25] Since students confront problems when integrating new knowledge into their long-term memory, research in science education in the previous two decades, has emphasized using different educational strategies to overcome the gap between students' perception of the natural phenomena and their mental models formed in their long term memory.[2,5,15,26]

Research also shows that students have considerable difficulty understanding the submicro and symbolic levels of chemical representations and that previous knowledge of a specific topic influences the integration of new science concepts into students' mental structure.[5,9,17,24,25,27,28] It is also necessary to emphasize that teachers use mostly the symbolic level of chemical concepts representations to teach chemistry at the primary, secondary, and university levels.[24] Using only the symbolic level of chemical concepts does not lead students to understand chemical phenomena at the particulate level.[29] The integration of the three levels of chemical representations according to the ITLS model, and students' exposure to the submicrorepresentations during the educational process, positively influence their more adequate understanding of the nature of the particles' interactions compared to those who learned the same concepts only by reading texts.[2,30] It is reasonable to believe that the use of different models (*e.g.*, submicrorepresentations, physical models) could improve the quality of the educational process and students` knowledge (*e.g.*, to visualize chemical equations, the correlation between structure and properties, *etc.*) and should therefore be more widely used.

Research has consistently shown that traditional lecture methods, in which teachers talk and students listen, dominate college and university classrooms.[31] To past passive learning to active learning and to find better ways of engaging students in the learning process, a Model of Active Learning has been developed, which suggests how teachers can develop a meaningful set of active learning activities (Fig. 2).[13]

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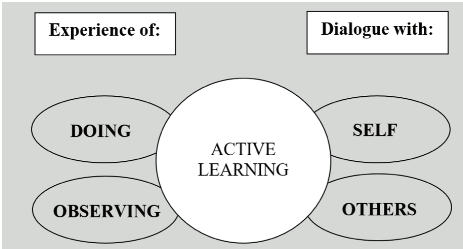

Fig. 2. Model of Active Learning (modified by Dee Fink[13]).

This model suggests that all learning activities involve some kind of experience or some kind of dialogue. The two main kinds of dialogue are "Dialogue with Self" and "Dialogue with Others". Two main kinds of experience are "Observing" and "Doing". Each of the four modes of learning described in the model above has its value, and using them can add variety to lessons and thus be more interesting for the learner. Furthermore, properly connected, the various learning activities can have an impact that is more than additive or cumulative; they can be interactive and thereby multiply the educational impact. Likewise, other research suggests that students must be actively involved in the learning process; they must do more than merely listen, they must read, write, discuss, do hands-on activities (*e.g.*, chemical experiments, constructing models, etc.) and must be engaged in solving problems.[13] Most importantly, students must be actively involved in the learning and teaching process, so that they become engaged in such higher-order thinking tasks as analysis, synthesis, and evaluation.

Use of the techniques and strategies that promote active learning in the classroom is vital because of their powerful impact on students' learning.[31] Many important activities that support active learning include teaching practices that focus on sense-making, self-assessment, and reflection on what worked and what needs improving.

These practices have been shown to increase the degree to which students transfer their learning to new settings and events. Subsequently, students also prefer strategies promoting active learning to traditional lectures. Those students who actively engage with the material are more likely to recall information later, and be able to use that information in different contexts.[32]

The term "active learning" means involving students in practicing important skills and in applying new knowledge.[33] However, the important elements of this active learning process can be described as follows: 1) reviews of previous learning, 2) point of showing how (where the teacher shows how to do), 3) a process of controlled practice (where the meaning and the process of the work are stressed), 4) a process of individual work, which is the heart of the learning process, 5) check of the work being done, 6) evaluation (assignments including review questions) and 7) final review: "What have we learned?"

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A very good example of an active learning process, with a very positive effect on the observers, in the chemistry teaching process is demonstrations, which are widely published and used by chemistry teachers at all levels. In addition to those, a long and distinguished history of demonstrations exists, with Faraday's lectures perhaps being the first real, lasting example of the impact of the chemical demonstrations on the audience. In short, there appears to be little doubt that the demonstrations excite and 'charm' the students and do have educational benefits.[34,35]

However, there are different opinions about the didactic approaches, even when conducting chemical demonstrations in the classroom. The literature asserts that guided and minimally guided instructional approaches are popular; yet, authors point out that approaches that ignore both structures and constitute human cognitive architecture are likely to be ineffective.[35–37] In this context, it is clear how important it is to incorporate the guided active learning approach into chemistry teaching, *e.g.*, chemistry experimental work, especially guided experimental work, in order to make the most of the use of chemical demonstration as a teaching tool in general. Undoubtedly, chemical demonstrations seem to have a significant effect on observers, if extended with the guided learning approach, at best the essence of the chemical content presented could be extracted.

For this reason, in our study we decided to implement the method of actively guided experimental work in the chemistry learning and teaching process.

METHODOLOGY

Research problem and research questions

Accepting the well-known recognition that students frequently have difficulty in learning science because they do not understand how macroscopic, particulate, and symbolic representations of matter are related, we attempted to introduce the context by applying the active learning method, in order to help the students understand these important relationships. With this in mind, a specially designed guided active learning method was developed to help students connect the macro- with the submicro-levels of chemistry, taking into account the well-known fact that demonstrations and experiments can contribute to active and meaningful conceptual learning.[36] Namely, learning theory and research on guided-learning instructions suggests that, unless students' concepts are linked in long-term memory, they will have an incomplete understanding of a given subject and that students are more likely to learn concepts when learning is active.[13,38,39] Accordingly, to follow the trends, the realisation of the active learning process – in our case, a method comprising guided active learning demonstrations (Experimental group 1 – EXP1) and guided active learning demonstrations with explanations at submicro level (Experimental group 2 – EXP2) was designed as a specific teaching approach that was incorporated into the educational process.

The main purpose of the study is therefore, to investigate the effect of two different teaching approaches (EXP1 and EXP2) on students' understanding of selected chemical concepts. Accordingly, we designed a guided active learning demonstration worksheet and presented it to students in (intervention) chemistry classes. The essence of this approach is represent in precisely divided and predicted steps that allow students to identify, analyze and exp-

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lain each step of the experiment. In this way, each specific macroscopic observation (previously identified by the teacher as important for understanding the nature of the chemical concept) was explained in detail, including sub-micro and symbolic level explanation. However, this was not the case in the control group, as this is not the usual practice of Slovenian teachers. Namely, the national chemistry curriculum in Slovenia does not prescribe a chemical experiment as a compulsory part when the teacher introduces chemical concepts to the students. In this sense, our chemistry teachers are free to decide whether or not to include a chemistry experiment in their lessons when a new chemistry topic is introduced in chemistry classes. However, Slovenian teachers often use chemical demonstrations, but only to increase students' interest in the chemistry topic, which leads students into the passive role. Therefore, we tried to overcome this by introducing the method of guided active learning demonstrations to change from passive to active role of students. Ergo, instead of students just admiring the chemical demonstration performed by the teacher, students were given an immediate opportunity to focus on and explain the essential parts of the experiment. Namely, by using the students' worksheet for guided active learning demonstrations, we enable students to realize the importance of each step, and also give them the opportunity to lean on the steps and follow the chemical experiment easily. In this sense, we give students the important time and place to analyze the crucial steps that are important to understand and further explain chemical phenomena introduced by the conducted chemical experiment.

These specific concepts (alkaline earth metal properties – AEMP) were selected because they are included in the school curriculum at all levels of education, and also because the Slovenian land is mostly composed out of limestone (calcium carbonate) and thus could be interesting for students.

According to the purpose of the research, one basic research question could be addressed: What is the influence of (EXP1) and (EXP2) on students' understanding of selected chemical concepts?

Based on the research question, four hypotheses could be formed:

H1: Students participating in EXP1 and EXP2 will score significantly higher on an achievement test than those students who were taught only at the symbolic level of the AEMP concepts.

H2: Students experiencing EXP2 will score significantly higher on the achievement test than those who participated in a EXP1.

H3: Students participating in EXP1, and in EXP2 will score significantly higher on a delayed achievement test than those students who were taught only the symbolic level of the AEMP concepts.

H4: Students experiencing EXP2 will score significantly higher on the delayed achievement test than those who experienced EXP1.

Participants

The research sample consisted of 171 students from four Slovene primary schools (94 males; 55.0 % and 77 females; 45.0 %). The average age of students involved in the research was 13.9 years (*SD* = 0.37 year). Sixty students (35.1 %) taught using only the symbolic representation of the selected chemistry content (CONT). A further fifty-one students (29.8 %) were involved in EXP1 and sixty-three students (36.8 %) in EXP2.

Experimental and control groups were compared according to some independent variables (general and science school success in the previous year, formal reasoning abilities, and pre-test achievements). These variables were selected because they can influence students' understanding of future chemical concepts to be taught. The one-way between-group analysis

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of variance (ANOVA) was conducted to explore the differences between the groups of students exposed to different teaching strategies (CONT, EXP1 or EXP2) in selected independent variables. The analysis of independent variables (the degrees of freedom (*df* (groups), *df* (students) = 2, 171) and significance of the differences between the groups (*Sig.*)) shows that the three groups were not statistically significantly different according to the selected independent variables (Table I).

TABLE I. ANOVA between groups of students exposed to three different educational strategies

Variable	Group	*M*	*SD*	*F* value	*Sig.*
General school success	CONT	4.3	0.66	0.195	0.823
	EXP1	4.4	0.64		
	EXP2	4.3	0.76		
Science school achievements	CONT	3.9	0.78	1.085	0.340
	EXP1	4.1	0.86		
	EXP2	4.2	0.77		
Formal reasoning abilities	CONT	3.3	2.25	1.498	0.226
	EXP1	2.9	2.58		
	EXP2	2.6	2.26		
Knowledge pre-test (KPT) achievement	CONT	3.8	1.61	2.115	0.072
	EXP1	4.0	1.72		
	EXP2	3.7	1.92		

Instruments

The instruments used in this research included the test of logical thinking (TOLT) and the knowledge pre-test (KPT) and two achievement tests: the achievement test applied immediately after educational strategy (AT-1), and a delayed achievement test (AT-2) administrated two weeks later. All chemistry achievement tests were designed specifically for this study. The description of the instruments is presented in the Supplementary material to this paper.

Research design

The selected chemistry content (alkaline earth metals properties – AEMP) was presented to two treatment groups using different teaching approaches: 1) the first treatment group received a guided active learning demonstrations (EXP1), and 2) the second treatment group guided active learning demonstrations with explanations at submicro level (EXP2).

Both teaching strategies also included symbolic representations using chemical formulae and equations. However, the (CONT) was taught using only the symbolic representation of chemical concepts, introduced without conducting a chemical experiment during the lesson and explaining it with submicrorepresentations.

Indeed, this is the normal practice used by Slovenian teachers since the national chemistry curriculum does not prescribe a chemical experiment as a compulsory part when the teacher introduces chemical concepts to the students. In this sense, our chemistry teachers are free to decide whether to include a chemical experiment in their lessons when a new chemical topic is presented in the chemistry room.

This design provided an opportunity to examine the effect of different teaching approaches on students' knowledge, specifically the main difference between the treatments and control groups. All the teachers involved in this study were familiar with the specific teaching approach, which they had to apply to their educational process. All teaching approaches were

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discussed in detail with the teachers, and specific modifications to the teaching strategy were made. More detailed description of teaching approaches is explained in the Supplementary material to this paper.

The instructions took 45 min in each group. All the students took the same set of instruments, administered at simultaneous intervals. The TOLT and knowledge pre-test (KPT) were administered two days before applying a specific educational strategy introducing AEMP to the students. After applying selected pedagogical strategies, the achievement test (AT-1) was administered at the end of the class and after fourteen days, according to Ebbinghaus theory, which states that forgetting occurs as a function of time. The rate of decay is highest in the first few days after learning the specific material; between days 6 and 31, learned material decays by only about 4 %[41] and 14 days after intervention it is useful to test knowledge retention. The delayed achievement test (AT-2) was used to collect data on students' knowledge stored in long-term memory about the AEMP. These instruments were used to control variables (formal reasoning skills, prior knowledge) that have been described in the research literature[4,9,42] as influential independent variables in the process of teaching chemistry using SMRs.

Descriptive statistics were obtained for illustrating the TOLT, KPT, AT-1 and AT-2 characteristics. Pearsons' correlation coefficients for determining the correlation between chemistry knowledge tests were calculated. Also, the one-way between-groups analysis of variance (ANOVA) was conducted to explore the differences between groups of students exposed to different teaching strategies, and to explore the differences in total success on achievement tests between the groups of students exposed to different educational strategies presenting AEMP.

RESULTS AND DISCUSSION

The results are presented on two levels: 1) results, obtained immediately after the applied educational strategy, and 2) results obtained after a 14-day period, to assess the level of knowledge retention. The results show students' better understanding of chemical concepts regarding AEMP when the educational strategy is applied by using active learning chemical demonstration or is even upgraded by explanation at the submicroscopic level, as when the symbolic representation of the same chemical concepts is applied.

It can be seen from Fig. 3, comparing the chemistry achievement scores from pre-test, test and post-test, that students experiencing EXP2 achieve the highest scores on both achievement tests (AT-1 and AT-2). The lowest scores were achieved by the students in the control group, where the alkaline earth metals were taught only by symbolic explanations of their properties. It can also be concluded from the results presented in this chart that students who had not experienced the submicro level explanations of the experimental observations did not reach the highest scores on achievement tests. More detailed results are presented below.

The influence of EXP1 and EXP2 on students' knowledge about AEMP immediately after the application of educational strategies

The first level of results shows students' achievements immediately after the specific educational strategy was applied.

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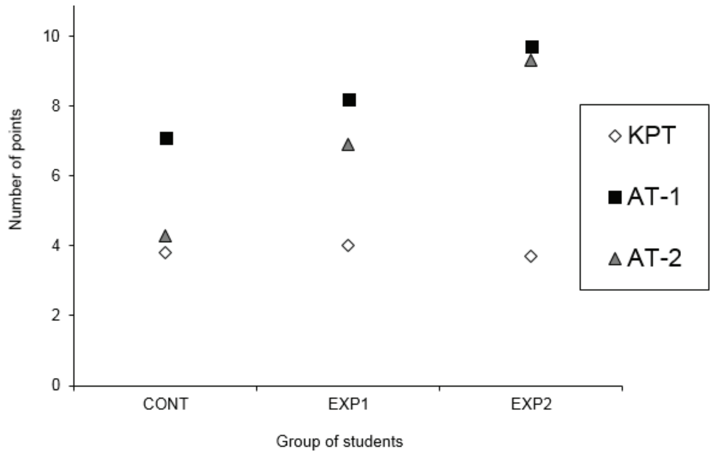

Fig. 3. Comparing the students' average achievements on three chemistry knowledge tests regarding AEMP.

It can be concluded from Table II that students exposed to the guided active learning demonstration supported by sub-microrepresentations were the most successful in solving the test. The lowest achievements were recorded in the control group**.**

TABLE II. Average achievement scores of students at AT-1 test (possible points 0–12); significances: CONT–EXP1, $p = 0.350$; CONT–EXP2, $p \leq 0.000$; EXP1–EXP2, $p = 0.004$

Group/number of students	Average AT-1 score	*SD*
CONT/60	7.07	1.72
EXP1/51	8.18	2.15
EXP2/63	9.73	2.04

The one-way between-groups analysis of variance (ANOVA) was conducted to explore the differences in total success on achievement AT-1 between the groups of students exposed to different educational strategies. The differences between the three groups of students are statistically significant ($F(2, 171) = 12.35$, $p < 0.001$). Post hoc comparisons using Tukey HSD showed a statistically significant difference ($p < 0.001$) between the mean scores for students in the control group and students involved in the EXP2 strategy. There is also a statistically significant difference ($p = 0.004$) in the AT-1 score between groups of students participating in the EXP1 and EXP2 strategy. There is no statistically significant difference ($p = 0.350$) between the control group of students and the EXP1 group.

The effect of EXP1 and EXP2 on students' long-term knowledge about AEMP

The second part of the results shows students' achievements on AT-2 obtained 14 days after the specific educational strategy was applied. The results

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can be interpreted as students' retained knowledge of the AEMP integrated into their-long-term memory.

Based on the results presented in Tables II and III, it can be concluded that students in the control group retained the lowest level of assessed knowledge; students received on average 2.77 (7.07–4.30) points less on AT-2 than on AT-1. However, the average score obtained by students in both experimental groups compared to the control group at AT-1 and AT-2 test was diminished by less than 2 points; 1.31 (8.18–6.87) points in the EXP1 group and 0.39 (9.73–9.34) points in EXP2 group. Table III shows that students participating in the experimental groups scored higher on the knowledge test than the control group 14 days after the educational strategies were applied. The highest average score was recorded in the EXP2 group.

TABLE III. Average achievement scores of students in the AT-2 test (possible points 0–12); significances: CONT–EXP1, $p \leq 0.000$; CONT–EXP2, $p = 0.001$; EXP1–EXP2, $p = 0.002$

Group/number of students	Average AT-2 score	*SD*
CONT/60	4.30	1.69
EXP1/51	6.87	1.83
EXP2/63	9.34	2.12

The ANOVA was also conducted to explore the differences in total success on achievement AT-2 between the groups of students participating in the specific strategy. The differences between the three groups of students are statistically significant ($F(2, 171) = 23.54$, $p < 0.001$). Post hoc comparisons using Tukey HSD showed that there is a statistically significant difference ($p < 0.001$) between the mean scores of students using only chemical symbolic language (CONT) and the EXP1 group of students. There is also a statistically significant difference ($p < 0.001$) between the CONT and the EXP2 group of students. The difference between the group of students participating in the EXP1 educational process and the group of students involved in the EXP2 educational strategy is statistically significant ($p = 0.002$).

This study was carried out to confirm the four hypotheses that were derived from the main purpose of the study and the research question, which was to investigate the effect of two different teaching approaches (EXP1 and EXP2) on students' understanding of AEMP immediately after the application of the educational strategy and after 14 days (effect of the teaching on students' long-term memory knowledge about AEMP).

The first hypothesis was: "Students participating in EXP1 and EXP2 will score significantly higher on an achievement test than those students who were taught only at the symbolic level of the AEMP concepts." The hypothesis cannot be confirmed. It can be concluded that a guided active learning demonstration (EXP1) for supporting the macroscopic level is not statistically significantly

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more effective on students’ chemical knowledge than teaching the alkaline earth metal concepts only at the symbolic level. In contrast, a positive effect of explaining selected chemistry concepts at the submicroscopic level in combination with a guided active learning method demonstration (EXP2) on students’ chemistry knowledge can be recorded, compared to the achievement test results of students that were taught only the symbolic level of chemical concepts. From this result, it can be summarized that a chemical demonstration alone, even though it is upgraded with students’ active observations, does not improve the students’ knowledge better than teaching chemistry only by the symbolic level written and explained by the teacher on the blackboard. It is important to emphasize that these findings support the findings of other researchers,[24,42,43] who concluded that symbolic teaching of chemistry is not effective, yet teachers mainly use the symbolic level of chemical concepts to teach chemistry. Even smaller impact on student understanding of chemical concepts can be expected if teachers do not use the guided active learning method in explaining selected chemical concepts at the submicroscopic level. The results obtained in the present study can be compared with several research studies. Namely, when students learn science in classrooms with minimal feedback, they are often lost and frustrated, and their confusion can lead to misconceptions, in particular when learning situations are unguided.[44,45]

The second hypothesis relates to the comparison between the achievement test scores of students experiencing a guided active learning demonstration followed by the AEMP concepts representations at submicroscopic level (EXP2) and those who participated in a guided active learning demonstration (EXP1). This hypothesis is confirmed. There is a significant difference in the achievement test (AT-1) scores between students exposed to the (EXP1*)* and students exposed to the (EXP2). These results are consistent with the conclusions of other researchers.[8,15,16,27] Gabel,[2] for example, reported that those students who were exposed to the submicrorepresentations during the educational process more adequately understand the nature of the particles’ interactions compared to those that learned the same concepts only by textbook reading. From the results obtained in this study, it can be concluded that explaining the macroscopic phenomena by submicroscopic representations is an important step while constructing adequate chemical knowledge because the knowledge obtained by submicroscopic explanations is more sufficient.

The third hypothesis is ‘Students participating in (EXP1) and in (EXP2) will score significantly higher on a delayed achievement test than those students who were taught only the symbolic level of the AEMP concepts.

The third hypothesis is confirmed. Knowledge obtained by the active learning in both cases is more persistent than knowledge constructed only by teaching chemical concepts at the symbolic level. This finding is interpreted as indicating

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that both treatments resulted in effective learning by the groups that experienced them: the students in both treatment groups learned more, and their knowledge was retained longer. These findings are in accordance with those of Kirschner *et al.*,[34] who claimed that, based on current knowledge of human cognitive architecture, minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning. The fact is that long-term memory is viewed as the central, dominant structure of human cognition, so everything we see, hear and think about is critically dependent on and influenced by our long-term memory.

The last hypothesis "Students experiencing (EXP2) will score significantly higher on the delayed achievement test than those who experienced (EXP1)" is also confirmed.

It can be concluded that learning chemical concepts at the submicroscopic level can influence constructing more persistent concept structure in students' long-term memory and that this adequately incorporated data can be recalled more easily when needed for solving new chemical problems. By achieving more stable chemical knowledge in students' long-term memory, we could enable students to build knowledge on a sound basis. This finding is a very important aspect of chemistry teaching and learning, because research shows that those students often do not have a proper knowledge base that would make it possible to upgrade their knowledge of more and more abstract chemical concepts when they make progress on the educational vertical.[5] Chittleborough and Treagust[43] also found that students' abilities to use and interpret chemical models (submicrorepresentations can also be regarded as models of particles) do influence their abilities to understand chemical concepts. These modelling skills should be taught (rather than left to be an incidental consequence of the teaching of chemical concepts) by being incorporated into instruction and by students being given practice in the application of multiple representations of chemicals and their interactions. According to these aspects and findings reported by Davidowitz *et al.*,[17] students need to model (draw) submicrorepresentations during their chemical education. Teachers should be aware of these activities so that they can use them when trying to explain specific phenomena at the submicroscopic level also to the students without properly developed modelling abilities.

CONCLUSION

The main conclusion of the study is that teaching the chemistry content – alkaline earth metals – to primary school students aged 14 years by guided active learning demonstrations and/or by guided active learning demonstrations with explanations at the submicroscopic level is more effective than traditional (blackboard – chalk symbolic) chemistry teaching. It can be concluded from the results that students' knowledge, obtained by either method, is more persistent and rem-

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ains stored in the students' long-term memory for longer periods. Knowledge stored in the long-term memory should be scientifically correct, and individual pieces of information should be vertically and horizontally connected into the adequate concept structure. For a student, such processed information is applicable to new educational situations and aids them in constructing new knowledge.

Further studies are needed to accurately interpret how a guided active learning demonstration supported by submicrorepresentations influences the students' long-term knowledge and how the guided active learning chemistry (GALC) strategy influences students' knowledge.[46]

In the future, the research should be applied on a larger scale in elementary school and transmitted at the secondary and university level. It is also important to stress that submicrorepresentations of chemical concepts affect students' proper knowledge development, as reported by some researchers, which is why the extra treatment group involving only submicrorepresentations in the teaching approach was not included in the "present study.[15,17,47] In future research, the influence of this variable to the students' knowledge incorporated into the active learning strategies, can also be explored. Other chemistry content can also be used for these teaching strategies. It is also important to emphasize that students lose knowledge after 14 days from learning concepts if they do not use it. AT-2 should, for that reason, be applied at the same sample a few times after the teaching, so that the dynamic of concept structure change in the students' long-term memory can be followed.

Overall, the data of this study seem to provide evidence that teachers should incorporate in their educational strategies either guided active learning demonstrations or even more effective guided active learning demonstrations with explanations at the submicroscopic level. In such a way, students could be prepared to challenge new science problems with adequate in-depth scientific knowledge in their further education, which may lead to more persistent and meaningful learning, based on the problem-solving approach.

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/10580, or from the corresponding author on request.

ИЗВОД

УТИЦАЈ АКТИВНОГ УЧЕЊА И РЕПРЕЗЕНТАЦИЈА СУБМИКРОСКОПСКОГ НИВОА НА РАЗУМЕВАЊЕ 14-ГОДИШЊИХ УЧЕНИКА О ЗЕМНОАЛКАЛНИМ МЕТАЛИМА

KATARINA SENTA WISSIAK GRM и IZTOK DEVETAK

University of Ljubljana, Faculty of Education, Kardeljeva pl. 16, 1000 Ljubljana, Slovenia

Циљ истраживања је био да се испита утицај два различита приступа на ученичко разумевање изабраних хемијских појмова. Прва група ученика у истраживању је подучавана методом активног учења вођеног демонстрацијама, а друга група је уз активно

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учење вођено демонстрацијама добила и објашњења субмикроскопског нивоа. У контролној групи одабрана тема је обрађена без активног учења вођеног демонстрацијама и без објашњења субмикроскопског нивоа. У истраживању су коришћени следећи инструменти: тест логичког мишљења (TOLT), пред-тест знања (KPT), два теста постигнућа (AT-1 и AT-2) и упитник за ученике. У истраживању је учествовао сто седамдесет један ученик (просечне старости 13,9 година). Резултати указују да су оба приступа (тј. активно учење вођено демонстрацијама, са и без објашњења субмикроскопског нивоа) ефикаснији од наставе искључиво на симболичком нивоу. Из резултата се може закључити да се знање ученика, стечено било којом методом која укључује вођено активно учење, задржава у дугорочном памћењу ученика. У раду су дискутоване импликације резултата истраживања на основношколски наставни програм у области природних наука.

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