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Internet pages for asynchronous online and face-to-face learning about solutions and dissolution

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Abstract: In the last decades online communication has become an important part of the realization of the educational process. In the conditions caused by the Covid-19 pandemic it has become particularly significant since in most cases it was necessary to switch to some forms of online teaching-learning. This paper presents the results of a research study conducted as a pedagogical experiment with parallel groups. The aim of this research study was to compare the effects of the application of internet pages for independent online asynchronous learning outside the school environment (group A) and face-to-face learning realized by a teacher at school (group B). The content of the internet pages was created in order to enable the acquisition of the concepts of solutions and dissolution. The effects of the approaches applied were studied based on the student achievement in a post-test (immediately upon learning about the concepts of solutions and dissolution) and in a delayed post-test (a year after the acquisition of these concepts). The participants in this research study were 187 primary school students, who participated in the pedagogical experiment when they were in the seventh grade, while they were in the eighth grade when they did the delayed post-test. The results showed that there was not a statistically significant difference between the overall achievements of the students who learnt about the concepts of solutions and dissolution by independent asynchronous online learning and face-to-face learning at school. This implies that the similar results can be achieved with asynchronous online learning as with face-to-face learning when the conditions do not allow school-based education.

Keywords: e-teaching; digital materials; submicroscopic level; educational video.

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INTRODUCTION

Various approaches and teaching/learning methods used for achieving educational goals/outcomes are continuously developed and proposed. Online learning is one of the methods used to organize teaching/learning which has shown an increasing potential for the improvement of the educational process in the last decades. Online learning is distance learning based on online communication with the application (distribution) of digital teaching materials. Due to the Covid-19 pandemic, teaching methods within which social contact among students at school is avoided, which reduces the risk of contracting the disease, have become particularly significant.[1] Faced with this novel situation, over 160 countries switched to online teaching/learning.[2]

Online learning can be divided into synchronous and asynchronous. Synchronous online learning includes real-time communication between the teachers and students *via* various communication media. The main advantages of this method are the possibility of obtaining an instant feedback[3] and increased student motivation due to their obligation to be directly involved in the teaching process.[4] Asynchronous online learning is time-independent communication, which supports work relation among learners and teachers when participants cannot be online at the same time.[5] One of the most available options is sending questions to the teacher *via* e-mail.[1] This has proven to be very significant in asynchronous learning since students avoid asking their teacher questions for various reasons, for example, in order to avoid drawing other students' attention. Students find asynchronous learning convenient due to the freedom of choice regarding the time and place when they access the learning material, learning dynamics and independence in doing the activities.[6] For these reasons, students find asynchronous online learning more satisfactory than synchronous online learning.[1] During the Covid-19 pandemic, there were situations when students were not able to participate in the organized synchronous online instruction. In these situations it was really important to enable them asynchronous instruction, for example, by posting a link to an educational video which served as a learning material.[7]

Apart from images, an educational video can also contain textual and audio information. Videos with an audio component have a greater potential for achieving learning outcomes compared to the ones accompanied only by textual explanations.[8,9] On the other hand, students remember better the information introduced through an educational video than the information introduced through a text or an audio, with or without images.[10] This is due to the fact that students pay more attention to the information introduced through video material than to the information introduced through a text or an audio recording.[11] With video materials it is possible to adjust the viewing dynamics to the tempo of information processing by stopping the video and watching it again, playing it again, slowing it down and speeding it up.[12,13] The research results have shown that multiple viewing of educational videos distributed to students via the YouTube platform has contributed to the improvement of their achievements by approximately 13 %.[14]

Some research studies have shown positive effects of asynchronous learning accompanied by the use of digital materials such as, for example, educational videos, while the results of some other research studies have shown that, as far as effectiveness is concerned, this approach does not differ from face-to-face approach.[15] This is explained by the fact that asynchronous learning fails to engage students' higher-order cognitive skills to a sufficient degree.[16,17] With asynchronous learning students can have difficulties with using the technology and understanding the content of the learning materials, but they can also experience a lack of motivation for this kind of learning or a lack of concentration.[18] The aim of this research study is to compare the effects of learning when internet pages, with digital materials about Solutions and Dissolution, are used in asynchronous online learning with the effects of learning within a class period held by a teacher at school.

EXPERIMENTAL

Based on the aim of this research study, the following null hypothesis was formulated: There is no statistically significant difference between the achievements of the seventh-grade students in Solutions and Dissolution after the application of internet pages for independent asynchronous online learning and the achievements of the seventh-grade students after face-to-face learning at school.

The proposed hypothesis was tested in a pedagogical experiment with parallel groups.

The sample

The pedagogical experiment was conducted with 187 seventh-grade students (aged 13–14) from two primary schools in the territory of Belgrade. The schools were selected based on the equipment available for the application of ICT (computers, projectors and a good internet connection), necessary for the realization of the pedagogical experiment. All seventh-grade students from the selected schools were included in the sample. The students were randomly divided into two groups: group A (N = 94) and group B (N = 93), formed by two classes from each school. The consent for conducting the pedagogical experiment was obtained from the management of both schools. The cooperation agreements were signed by the Dean of the University of Belgrade – Faculty of Chemistry, and the school principals. Written consents for the participation of students in this research study were obtained from the students' parents/guardians. The parents/guardians and students were informed in detail about the aim of the research study, the method of its realization and students' roles in the research study. It was pointed out that the participation is on a voluntary basis and data confidentiality was guaranteed. It was explained to the students that they would not be rewarded for their participation in the research study and that there would be no consequences if they decided to withdraw from the research study. Students could withdraw from the research study at any moment.

Design and procedure

The research study was organized during the lesson on Solutions and Dissolution, the first one within the thematic unit Solutions according to the chemistry curriculum for the seventh grade of primary school. Understanding the contents about Solutions and Dissolution depends on understanding the concepts from the curricular thematic unit The Structure of Substance. A description of the activities done with each group of students (A and B) in the pedagogical experiment is provided in Table I.

TABLE I. The plan for the pedagogical experiment implementation

Activity	Group A activities	Group B activities
1.	Pre-test	Pre-test
2.	Asynchronous online learning by independently accessing the internet pages on Solutions and Dissolution, outside the school	Face-to-face learning by the application of the internet pages on Solutions and Dissolution, at school with teacher guidance
3.	Post-test	Post-test
4.	Delayed post-test	Delayed post-test

At the beginning of the research study both groups were tested by a pre-test, which tested the groups' previous knowledge. Students from Group A were given a link for accessing the internet pages for independent asynchronous online learning and instructions on how to access the internet pages before their next chemistry lesson.

Students from Group B learned about Solutions and Dissolution using the same internet pages at school, with teacher guidance. The internet pages used as a teaching material were created in line with the outcomes defined by the seventh grade chemistry curriculum. The teaching material on the internet pages was prepared with the aim of enabling students to understand the process of dissolving at the submicroscopic (particles) level. The content of the internet pages was presented in the textual, visual (images, video recordings and animations) and audio format (narration). The introductory part of the content about Solutions and Dissolution was given in the textual form, while the other parts were given in the form of educational videos. As a key segment of the internet pages, the educational videos included animations which showed the process of dissolution of an ionic substance and a non-polar substance at submicroscopic level, accompanied by the narration by the author/researcher. Video 1 shows the dissolution of an ionic substance in a polar solvent. Video 2 shows the dissolution of a non-polar substance in a non-polar solvent.

Apart from being shown the content of the same internet pages, the students from Group B learnt about Solutions and Dissolution by listening to their teacher talk on this topic during the chemistry class period. After the class period, the students from Group B did not have an opportunity to access the internet pages. During the 35-min lesson students listened to their teacher's lecture which included watching educational videos with the explanations which accompanied the digital material. After that, the teacher checked students' understanding of the process of dissolving ionic and non-polar substances through a ten-minute conversation with the students. In the next chemistry class period, students from both groups did a post-test. The time available for the completion of the post-test was 45 minutes. A year after the post-test, the groups made up of the same students were tested again. The delayed testing was conducted in order to measure retained learning about Solutions and Dissolution in each group a year after they had learnt about these concepts.

Instruments

In order to collect data in this research study two tests for knowledge assessment were designed and administered to all students. Both tests were paper-pen tests. The pre-test was used to check students' knowledge of the concepts within the thematic unit The Structure of Substance, key to understanding the concepts of Solutions and Dissolution.[19] The pre-test had six questions with eight items altogether: three open-ended (short-answer) and five closed-ended (multiple-choice questions). The questions included the following content: the types of chemical bonds in compounds, chemical formulae of compounds, types of particles in the crystal of an ionic compound and the dipole.

The same test was used for the purpose of post-testing and delayed-testing. The test contained eight questions with ten items altogether. Six questions were closed-ended questions (two questions, each with two items, were alternate-choice questions; four questions were multiple-choice questions). Two questions in the test were open-ended (essay-type) questions. Four questions tested students' understanding of the dissolution of an ionic substance in a polar solvent. In the test this process was presented by an illustration at the submicroscopic level. The other four questions in the test checked the students' understanding of the process of dissolving a non-polar substance in a non-polar solvent. An illustration showing this process at the submicroscopic level was given in this part of the test as well. During post-testing, the educational videos about the dissolution of ionic and non-polar substances, which had been used as teaching material on the internet pages, were played the whole time. The students were expected to identify the type of chemical bonding in the solutes and the solvents based on the illustrations given within the questions in the tests and the educational videos played. Students were also asked to describe the formation of each solution at the submicroscopic level, considering the type of chemical bond in the solute and in the solvent.

Video 1 contained the information necessary for responding to items 1a, 1b, 2, 3 and 4 of the test. Video 2 contained the information necessary for responding to items 5a, 5b, 6, 7 and 8.

The tests were reviewed by the experts in the field of chemical education, who were not involved in their design, in order to assess their validity with respect to the defined aim of the research and the hypothesis. The two chemistry teachers who enabled the realization of the research study and the members of the Department of Chemical Education, the University of Belgrade – the Faculty of Chemistry, examined the content of the tests, upon which the necessary revisions of the tests were made.

RESULTS AND DISCUSSION

The results obtained in the tests are presented below.

The distribution of the results in the pre-test, post-test and delayed post-test

The maximum score which students could achieve in the pre-test was 8 points, while it was 10 points in the post-test and delayed post-test. The characteristics of the distribution of the scores of both student groups are presented in Table II. The following data are presented: the number of students in each group (*N*), the minimum (*Min*) and maximum (*Max*) number of correct answers in each test, the mean (*Mean*), the standard deviation (SD), the contribution of correct answers (*C*), the skewness value and the kurtosis value. The mean score of Group A in the pre-test (5.11) was higher than the mean score of Group B (4.83). In the post-test, Group B (5.54) was more successful than Group A (5.20). The mean score achieved by Group A in the delayed post-test (4.45) was higher than the mean score achieved by Group B (4.35).

TABLE II. Descriptive statistics of student achievement in the pre-, post- and delayed post-test

Testing	Group	*N*	Number of correct answers				C / %	Skewness	Kurtosis
			Min	*Max*	*Mean*	*SD*			
Pre-test	A	94	1	8	5.11	1.72	63.8	0.013	−0.655
	B	93	0	8	4.83	2.16	60.4	−0.338	−0.033
Post-test	A	94	1	8	5.20	1.61	52.0	−0.226	−0.351
	B	93	2	8	5.54	1.46	55.4	−0.162	−0.477
Delayed	A	94	2	8	4.45	1.52	44.5	0.590	−0.079
post-test	B	93	2	8	4.35	1.28	43.5	0.283	0.018

The skewness and kurtosis values were used as the criterion for assessing the normality of the distribution of the obtained results. The obtained values range from −1 to +1, which indicates that the data have a normal distribution. Based on this, it was decided to apply the independent-samples *t*-test in order to determine whether there was a statistically significant difference between the means in Groups A and B. The obtained data are presented in Table III.

TABLE III. The value of the *t*-test for the results of Groups A and B

Value	Pre-test	Post-test	Delayed post-test
t	0.97[a]	−1.49[a]	0.45[a]
p	0.33[b]	0.14[b]	0.66[b]

[a]Confidence interval - less than 95 %; [b]*p*-value – more than 0.05

The value obtained by the *t*-test shows that there is no statistically significant difference between the mean scores achieved by Groups A and B in the pre-test. Based on this, it was concluded that both groups of students were at the same level regarding their previously acquired knowledge. There were no statistically significant differences between the mean scores achieved by Groups A and B in the post-test and the delayed post-test. It can be concluded based on the obtained results that the application of the internet pages on Solutions and Dissolution for independent asynchronous online learning outside the school environment contributes to similar achievements as face-to-face learning with the same internet pages in the school environment with teacher guidance. These results are consistent with previous research studies, which have shown the same students' scores after online and face-to-face course in inorganic chemistry[20] and after introductory chemistry lectures and laboratories.[21]

Student achievement in the pre-test questions

Table IV shows the number of correct answers (frequency, *F*) expressed as the contribution of correct answers given by the students from both groups to the pre-test items. The values of the *t*-test, used for assessing the statistical significance of the difference and the *p*-values (*p*) are presented.

TABLE IV. The pre-test results in Groups A and B

Item	Group A		Group B		*t*-test	*p*
	F	Contribution, %	*F*	Contribution, %	A–B	
1	69	73.4	65	69.9	0.53[a]	0.597[b]
2a	30	31.9	27	29.0	0.43[a]	0.671[b]
2b	37	39.4	25	26.9	1.82[a]	0.070[b]
2c	36	38.3	30	32.3	0.86[a]	0.390[b]
3	68	72.3	63	67.7	0.68[a]	0.495[b]
4	85	90.4	82	88.2	0.50[a]	0.620[b]
5	89	94.7	81	87.1	1.81[a]	0.073[b]
6	66	70.2	76	81.7	−1.85[a]	0.066[b]

[a]Confidence interval - less than 95 %; [b]*p*-value – more than 0.05

In Group A, the contribution of correct answers to individual pre-test items ranged from 31.9 to 94.7 %, while it ranged from 26.9 to 88.2 % in Group B. The students from Group A were less successful than the students from Group B at only one item (item 6). The results obtained by the *t*-test did not show a statistically significant difference between the contributions of correct answers in the groups for any of the pre-test items. This confirmed that the students from Group A and Group B had similar previous knowledge of the concepts from the thematic unit The Structure of Substance.

Student achievement in the post-test and delayed post-test questions

Table V shows the number of correct answers (frequency, *F*) and the contribution of correct answers to the items of the post-test and delayed post-test in both groups.

TABLE V. The results of the post-test and delayed post-test in Groups A and B; number of correct answers (*F*) and the contribution of correct answers (*CA*)

Item	Post-test						Delayed post-test					
	Group A		Group B		*t*-test	*p*	Group A		Group B		*t*-test	*p*
	F	*CA* / %	*F*	*CA* / %	A–B		*F*	*CA* / %	*F*	*CA* / %	A–B	
1a	87	92.6	89	95.7	−0.91	.363	63	67.0	66	71.0	−0.58	.562
1b	84	89.4	91	97.8	−2.40[a]	.018	83	88.3	86	92.5	−0.96	.336
2	45	47.9	38	40.9	0.96	.337	28	29.8	26	28.0	0.28	.784
3	36	38.3	34	36.6	0.24	.807	31	33.0	20	21.5	1.77	.079
4	6	6.4	0	0.0	2.52[a]	.013	0	0.0	1	1.1	−1.0	.316
5a	82	87.2	80	86.0	0.24	.809	61	64.9	75	80.6	−2.45[a]	.015
5b	82	87.2	86	92.5	−1.18	.238	74	78.7	76	81.7	−0.51	.609
6	26	27.7	42	45.2	−2.52[a]	.013	45	47.9	31	33.3	2.04[a]	.043
7	41	43.6	55	59.1	−2.14[a]	.034	31	33.0	24	25.8	1.07	.284
8	0	0.0	0	0.0	0	-	2	2.1	0	0.0	1.41	.159

[a]The difference in the contributions of correct answers by Groups A and B statistically significant at the level $p < 0.05$

It also shows the values obtained by the *t*-test, which was used to assess the statistical significance of the difference between the contributions of correct answers achieved in Groups A and B, as well as the *p*-values for the given values of the *t*-test.

In the post-test, the contribution of correct answers to individual items ranged from 0 to 92.6 % in Group A, and from 0 to 97.8 % in Group B. The students in Group A had the larger number of correct answers to four items, while the students in Group B had the larger number of correct answers to five items. A statistically significant difference between the contributions of correct answers given by Groups A and B was found for four post-test items. The students in Group A were statistically significantly more successful at one post-test item (item 4). The students from Group B were statistically significantly more successful at three items (1b, 6 and 7).

The results of the post-test show that, after seeing Videos 1 and 2 (the content of the internet pages), over 86 % of the students were able to differentiate between the models of the solute particles and the models of the solvent particles. In one of the four items which related to differentiating between the ions of the solute and the molecules of the polar solvent and between the molecules of a non-polar substance and non-polar molecules of the solvent, the students from Group B achieved a statistically significantly higher contribution of correct answers. In this item, students were asked to identify the models showing polar molecules of the solvent (item 1b). During the learning process, the students from Group B watched the models of the presented solvent particles (Video 1) while listening to their teacher who explained the models showing the particles. In this case, watching and listening to the content turned out to be more effective than watching and reading.[22]

A slightly higher contribution of students from Group A identified the ionic bond in the dissolved substance, but a statistically significantly higher contribution of students from Group B identified the non-polar covalent bond in the solute molecules (item 7). Since students from Group B were more successful at recognizing the type of particles which make up the solute (item 6), they were expectedly more successful at identifying the type of chemical bond in the solute molecules. Explaining the dissolution process at the submicroscopic level presented the biggest problem for both groups. The process of dissolving both ionic and non-polar covalent compounds was presented using particle models. The explanation of the dissolution of an ionic substance in a polar solvent was provided by only 6 students from Group A (item 4). None of the students provided an explanation of the dissolution of a non-polar covalent substance in a non-polar solvent. It can be concluded, based on the obtained results, that the largest number of students could differentiate between the solute and solvent particles in the watched educational videos, but fewer than half of the students named the types of particles and the type of chemical bond in the solute based on the models. The representations of ion models and models of polar and non-polar molecules did not contribute to a better understanding of the dissolution process at the submicroscopic level. These results are consistent with the previous research studies which had shown that students found it difficult to interpret and explain observations of phenomena and to relate them to the models of submicroscopic level of matter.[23] Therefore, it is always necessary to develop learning practices in chemistry which emphasise representations of the submicroscopic level.

The contribution of correct answers to the individual items in the delayed post-test ranged from 0 to 88.3 % in Group A and from 0 to 92.5 % in Group B. The total number of correct answers was lower in both groups in the delayed post-test compared to the post-test. In the delayed post-test, students were also most successful at differentiating between the models of solute and solvent particles (the contribution of correct answers was higher than 65 %). In both groups, less than one third of students could successfully identify the type of solute and solvent particles. Both groups were more successful at identifying the type of particle in the case of a non-polar solute than in the case of an ionic solute. There were more correct answers to both items in Group A, but the difference is statistically significant for the identification of the particles of the non-polar covalent substance. The students from Group A were more successful than the students from Group B at identifying the type of chemical bonding in the solutes. It can be observed for Group A that the contribution of students who correctly named the ionic bond is higher than the contribution of students who identified an ion as the type of solute particle. In the delayed post-testing, none of the students from Group A explained the process of dissolution of a polar substance in a polar solvent. The situation is slightly different with the explanation of the dissolution of a non-polar substance. Two students from Group A explained the dissolution process and none of the students from Group B. The insight into the retention of the acquired knowledge based on the delayed post-test results indicates that the watched videos enabled more than two thirds of the students to be successful at differentiating the model of solute particles from the model of solvent particles. Group A was more successful at identifying the type of particles and chemical bond in the solute, while both groups were more successful at identifying the type of particle and chemical bond in the case of a non-polar substance.

The presented results show that the digital material, created for the acquisition of the concepts of Solutions and Dissolution and posted on the internet pages, can be used both in the conditions of regular school education and for independent asynchronous online learning. Online distribution of digital materials for independent learning can be an additional method within the usual realization of the teaching process, but the fact that it can be used as a particularly useful teaching method when face-to-face teaching is not possible, as was the case in the conditions caused by the Covid-19 pandemic, is particularly significant.

CONCLUSION

The conducted research study is a pilot study of the effects of the internet pages with contents about Solutions and Dissolution on the seventh-grade students' achievements when the pages are used for independent asynchronous online learning (student group A) and when they are used in the class with explanations provided by the teacher (student group B). According to the pre-test results, Groups A and B were at the same level as far as their previous knowledge was concerned. The post-test and delayed post-test results showed that there was not a statistically significant difference between the overall achievements of the students who had studied independently asynchronously online and the ones who had studied in the face-to-face instruction. These results confirmed the proposed null hypothesis that the seventh-grade students' achievements in Solutions and Dissolution do not statistically significantly differ after the application of the internet pages for independent asynchronous online learning outside their school and face-to-face learning at school. In both groups, the achievements in the delayed post-test were lower than in the post-test. There was not a statistically significant difference between the mean values achieved by the groups in the delayed post-test. This indicates that the retention of knowledge acquired by asynchronous online learning is similar to the retention of knowledge acquired with teacher guidance. Even though the difference between the achievements of the two groups is not statistically significant, it is important to point out that Group A, which experienced asynchronous online learning, had a worse score than Group B in the post-test, while it had a slightly better score in the delayed post-test. This suggests the stability of the knowledge acquired by independent asynchronous online learning.

Apart from the overall results, the results achieved in individual items of the post-test and the delayed post-test were analyzed for both kinds of learning immediately upon learning and a year after learning. It was established that the application of educational videos (Videos 1 and 2), in which the dissolution processes are presented through the models of solute and solvent particles, had enabled the largest number of students to identify the models of solute and solvent particles. Better achievements of the students from Group B in these items indicate that additional teacher narration with explanations (which were given through images and texts in the educational videos) had enabled students to better identify the presented models of particles. A relevant implication of this research is that in the preparation of the material/videos for asynchronous online learning, textual explanations should also be given in the audio format. Compared to identifying the models of solute and solvent particles, a smaller number of students correctly identified the types of solute particles and the type of chemical bond in the solute and the solvent. In the delayed post-test both groups were more successful at identifying the type of particle and chemical bond in the case of the dissolution of a non-polar covalent substance. The results achieved within individual items in both groups show that students find it difficult to explain the process of dissolution by relating it to the models at submicroscopic level of matter. One way of dealing with these difficulties could be a wider and constant application of the representations of the submicroscopic level in the chemistry teaching/learning practice.

The results obtained within this research study are important for the situations when it will be necessary to make decisions about the methods of chemistry teaching/learning due to various circumstances. Since the learning outcomes were equivalent for both teaching/learning approaches we have investigated, the application of the independent asynchronous online learning outside the school environment can be recommended in the conditions when it is not possible to organize face-to-face learning with teacher guidance in school classes. In the context of the current limitations to the realization of face-to-face teaching/learning due to the coronavirus pandemic, this conclusion has an immediate and current application. Furthermore, it is relevant for some future situations in which, for various reasons, it might be estimated that pedagogic teacher-student interaction at school environment is not possible. The main limitation of this research study is the size of the sample. The number of students participating in the research study is not sufficient to make generalizations. The choice of schools which participated in the research study was influenced by the IT equipment available since it was essential for conducting the pedagogical experiment. In addition to this, the duration of the study is relatively short and limited to the realization of one lesson. The future research studies should focus on the comparison of the investigated approaches when some other chemistry contents are introduced and elaborated. It should be pointed out that students from Group A were new to independent online asynchronous learning as a teaching/learning method. In their learning experience prior to the conducted research study, the students had never participated in any activities which included the above-mentioned approach, so a certain adjustment was probably necessary. Meanwhile, students at all educational levels have gained new experience of online teaching/learning. This experience will help overcome some potential problems in conducting new research studies which will aim at comparing the efficiency of online and face-to-face teaching/learning.

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ИЗВОД

ИНТЕРНЕТ СТРАНИЦЕ ЗА АСИНХРОНО “ON-LINE” УЧЕЊЕ И УЧЕЊЕ У УЧИОНИЦИ О РАСТВОРИМА И РАСТВАРАЊУ

ЛИДИЈА Р. РАЛЕВИЋ, БИЉАНА И. ТОМАШЕВИЋ и ДРАГИЦА Д. ТРИВИЋ

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Последњих деценија on-line комуникација је постала важан део у реализацији образовног процеса. Под условима Covid-19 пандемије то је било значајно јер се у највећем броју случајева морало прећи на неке од облика on-line наставе/учења. У раду су представљени резултати истраживања, спроведеног као педагошки експеримент са паралелним групама. Циљ овог истраживања је био да се упореде ефекти примене интернет страница за самостално on-line асинхроно учење ван школе (група А) и наставе/учења коју реализује наставник у школи (група Б). Садржај интернет страница припремљен је за усвајање појмова раствори и растварање у седмом разреду основне школе. Ефекти примењених приступа испитивани су на основу постигнућа ученика на пост-тесту (непосредно након учења) и на одложеном пост-тесту (годину дана након примењених приступа). У истраживању је учествовало 187 ученика који су у педагошком експерименту учествовали као ученици седмог разреда основне школе, а потом на одложеном пост-тесту као ученици осмог разреда. Резултати су показали да не постоји статистички значајна разлика између укупних постигнућа ученика који су појмове раствор и растварање усвајали путем самосталног асинхроног on-line учења и наставе/учења коју у школи реализује наставник. То имплицира да је могуће под условима који не дозвољавају организовање наставе у школи, асинхроним онлајн учењем постићи резултате сличне резултатима наставе у школи.

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