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Effects of a 5Es learning model on the conceptual understanding and science process skills of pre-service science teachers: The case of gases and gas laws●

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Abstract: The aim of this study was to investigate the effects of using a 5Es learning model on the pre-service science teachers' conceptual understanding and science process skills for "gases and gas laws". The sample of the study consisted 49 pre-service science teachers enrolled for the "Science Laboratory Practices-I" course within the department of science education of a Turkish state university. Through a quasi-experimental research method (pre- and post--test research design), an experimental group was exposed to the 5Es learning model (engage-explore-explain-elaborate-evaluate) with different conceptual change methods/techniques (*i.e.*, worksheets, computer animations, analogies and experiments). A control group was also taught through existing instruction (*e.g.*, experiments, lecture and question–answer). Data were collected through the gas laws test and the science process skills test. The results of partial eta squared (η^2) revealed large-size effects for the control (0.61) and experimental groups (0.73). The 5Es learning model was more effective than the existing instruction in overcoming the pre-service science teachers' alternative conceptions of "gases and gas laws", as well as in improving their science process skills. The current study recommends that the 5Es learning model be tested with a larger sample throughout a long-term teaching intervention.

Keywords: chemistry education; conceptual change; science process skills.

INTRODUCTION

The properties of gases are difficult to observe with the naked eye; furthermore, they are explained by abstract ideas and laws, making them difficult for students to understand.[1,2] Conventional teaching methods have shortcomings

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with facilitating students' learning of fundamental molecular behaviors (*e.g.*, interlinks at macroscopic, sub-microscopic and symbolic levels) and developing graphical skills of "gases and gas laws".[3–4] Similarly, chemistry textbooks have generally handled the subject of "gases and gas laws" within procedural learning instead of conceptual understanding.[5] Since everyday life experiences informally shape students' conceptions of the subject of "gases and gas laws",[6,7] several alternative conceptions (see Table S-I of the Supplementary material to this paper) have been developed by students from different grades (7th, 10th and 11th grades), pre-service and in-service teachers.[2,5,7–13] Identifying these alternative conceptions is critical for determining the steps needed to support conceptual change.

Unfortunately, teachers may be the inadvertent source of students' alternative conceptions, because they either miscommunicate information or have their own alternative conceptions. It is important that teacher preparation programs are aware of this issue. Given these arguments, conceptual change researches have employed varied pedagogical approaches related to the subject of "gases and gas laws". These include problem-based learning,[13] research-based approach,[11,14] research-based computer simulations,[15] conceptual change-oriented instruction,[9,12] hands-on laboratory activities accompanied with computer modeling,[16] argumentation-based pedagogy,[17] augmented virtual science laboratories[3,18] and case-based instruction.[7] Of these studies, only three concentrated on teacher preparation programs and studied with pre-service teachers.[11,13,17] Pabuccu and Erduran[19] called for more studies related to facilitating pre-service science teachers' understanding of the gases and gas laws. The current study, therefore, was undertaken in response to this call.

Even though conceptual change methods used in the aforementioned studies were somewhat effective in overcoming the pre-service science teachers' alternative conceptions related to "gases and gas laws", some of their participants were still resistant to change even after the teaching intervention. Hence, the implications for future research in these studies recommended enhancing pre-service science teachers' conceptual change levels.[20] Furthermore, studies have shown that using only one type of conceptual change method may limit students' learning motivation and satisfaction.[20,21] Previous studies used only one or two conceptual change method(s)/technique(s)[3,7,12,14–17] instead of combining various conceptual change methods/techniques within the 5Es learning model. By doing this, the current study illustrated an alternative pedagogical approach for gases and gas laws and enriched the learning environment with different conceptual change methods/techniques.

Science process skills (SPS)

School science courses explicitly focus on content knowledge, while SPS implicitly includes scientific attitudes, scientific communication, scientific arg-

umentation and so forth as well.[22] However, science education literature continues to debate which is more important: SPS or content knowledge.[23] That is, SPS drives the doing of science, whilst science content is the knowing of science.[24] There are basically two ways to develop SPS, either through teaching SPS solely, and directly or by integrating SPS into content knowledge.[24] The first one designs specific science activities for each of the SPS to help students learn how to do science, the nature of science and the origin of facts. The second one integrates SPS into science content knowledge and employs the power of activity-based learning. The latter approach offers a context for both SPS and content.[24] That is, science experiments/activities deploy SPS while teaching science content knowledge. Scharmann[25] supports that teaching science content knowledge and SPS simultaneously helps them complement each other. This combined approach is more promising as it leverages regular content teaching time to develop SPS. We, therefore, adhered to this view while designing the current study.

To illustrate the interconnection between content knowledge and SPS, experiments are used to teach SPS development, while SPS is the tools for learning content knowledge. For example, while students test how temperature affects the volume of a fixed quantity of gas (Charles Gas Law), they observe, measure, identify variables, formulate hypotheses, interpret data, define operationally, do experiments and formulate models. Students will learn by doing and experiencing personally how to access information about this process. Hence, SPS plays a key role in teaching and learning scientific knowledge.[26,27] A review of the literature shows other studies that support the idea of integrating SPS and content knowledge to: *i*) improve better understanding of subject/topic/content, *ii*) facilitate science learning and *iii*) encourage students to take their own responsibility for their learning through the scientific inquiry process.[22,24,25,28,29]

Furthermore, developing SPS helps to improve higher-order-thinking skills, such as problem solving, critical thinking, and decision making.[29] Along the same lines, SPS and scientific literacy overlap with each other. SPS promotes components of scientific literacy, such as the ability to think scientifically, the ability to use scientific knowledge in problem solving, appreciation of science, and the ability to think critically about science and scientific expertise.[30] Despite the advantages of developing individuals' SPS outlined above, pre-service teachers still have a poor understanding of such skills[31,32] and also possessed pitfalls in performing the basic and integrated SPS.[32] Hence, this necessitates an alternative pedagogical approach that more directly emphasizes SPS.

Relationship between science curriculum and science process skills

To achieve the targeted goals of science education (*i.e.*, conceptual understanding, SPS, critical thinking), science education studies of conceptual change

and constructivist learning theory have focused on the students' pre-existing knowledge to enhance scientific understanding through active engagement and ensure ownership of the constructed ideas.[21,28,29] For example, the most recent versions of the Turkish science curricula emphasize student engagement, creative thinking, innovative thinking, constructivist learning theory, as well as varied teaching methods/strategies to stimulate students' interests in science.[29] These studies claim that the 5Es learning model (engage-explore-explain-elaborate-evaluate), which enriches the learning environment with different conceptual change methods, significantly increases the probability of achievement gains (*i.e.*, conceptual understanding, long-term learning, developing SPS, logical--creative-reasoning skills) in science classes.[21,28,30,31]

Any educational change (*e.g.*, constructivist learning theory) promotes national educational systems to update to the needs of new trends (*i.e.*, economic development, work force). For example, the Turkish science curricula have challenged traditional or teacher-centered instruction and fostered any innovative view for science learning and teaching. Even though various learning models of constructivism have been launched, *e.g.*, 3Es (explore-explain-elaborate, called learning cycle), 4Es (engage-explore-explain-evaluate), 5Es and 7Es (excite-explore-explain-expand-extend-exchange-examine),[38] the most recent versions of the Turkish science curricula have especially suggested the 5Es learning model.[20,33] Since each "E" represents a particular part of the learning process and calls for varied conceptual change methods/techniques (*i.e.*, computer animation, worksheet, analogy and experiment), the 5Es learning model purposes to actively assist students in linking their prior knowledge with new concepts. Due to the aforementioned issues,[20,29,33] the Turkish science teacher education programs have paid more attention to the 5Es learning model. Therefore, pre-service experiences of teachers (*e.g.*, 5Es learning model, SPS and content knowledge) should be enhanced within teacher preparation programs since qualified teachers are only able to choose and use proper pedagogical approaches in their classrooms. In other words, teacher preparation programs should not only equip pre-service teachers with these abilities but also pedagogically illustrate how to integrate these approaches into science classes. Hence, science educators should look for any alternative pedagogical approach challenging any negative disposition towards deeper conceptual understanding and SPS. Given the interaction between content knowledge and SPS, the current study explored the degree to which the 5Es learning model makes concepts of abstract chemistry understandable and/or meaningful. In summary, the current study integrated content knowledge and SPS within the 5Es learning model to facilitate conceptual, procedural and multidimensional functional levels of scientific literacy.[34]

The 5Es learning model guides teaching and learning processes in science classes[21,33,34] by stimulating the pre-service science teachers' learning capacities

of the subject of "gases and gas laws" drawn from the regular general chemistry curriculum in the science teacher preparation program. Even though some studies investigated the effect(s) of the 5Es learning model with varied conceptual change on the pre-service science teachers' understanding of other science subjects (*e.g.*, electrochemistry),[20] none of the earlier studies tested how the 5Es learning model facilitates the pre-service science teachers' understanding of the subject of "gas and gas laws" and SPS. On the other hand, previous studies have also highlighted that the 5Es learning model directly influences their conceptual understanding and SPS rather than the content/topic (*e.g.*, gas and gas laws) or separate techniques (*i.e.*, computer animation, worksheet, and analogy).[20,21,28]

To address the goal of the current study, the researchers utilized worksheets, computer animations, analogy/analogical reasoning, experiments, and SPS within the 5Es learning model. For example, while the pre-service science teachers actively discovered the Charles Gas Law (content knowledge) in small groups of three or four, they employed such SPS as identifying variables, formulating hypotheses, performing experiments, interpreting data and defining operationally. In this way, they wrote their observations down on the worksheet (see Appendix 1 of the Supplementary material) and discussed their results to reveal the Charles Gas Law. Hence, they linked content knowledge (*i.e.*, Charles Gas Law) with SPS and constructivist learning (*i.e.*, the 5Es learning model). The researchers, in turn, hypothesized that the 5Es learning model would result in better conceptual understanding of the subject of "gases and gas laws" and improvements in their SPS. In addition, their combined pedagogical features (*i.e.*, content knowledge, SPS and constructive learning) may boost the pre-service science teachers' learning capacities in practicum. Therefore, the aim of this study was to investigate the effects of using the 5Es learning model on the pre-service science teachers' conceptual understanding and SPS for gases and gas laws. The following research questions guided the current study:

1. How do the 5Es learning model and existing instructions influence the pre-service science teachers' conceptual understanding of "gases and gas laws" and SPS?

2. Are there any significant differences between the experimental and control groups' pre- and post-test mean scores of the gas laws test and SPS test?

EXPERIMENTAL

Through a quasi-experimental research design (with a non-equivalent pretest–post-test control group),[7] the study investigated the effects of independent variables (*e.g.*, the 5Es learning model and existing instruction) on the dependent variables (*e.g.*, the pre-service science teachers' conceptions and development of their SPS). The Department of Science Education under investigation possessed two regular cohorts (Classes A and B) for the third-year of the four-year teacher preparation program. Hence, the experimental (15 females and 9 males) and control (15 females and 10 males) groups were randomly assigned to these two cohorts

instead of individually assigning the participants to the groups. Each group was exposed to different teaching designs (*i.e.*, the 5Es learning model and existing instruction) for the same duration (*i.e.*, 8 class-hours). After the teaching intervention, the post-tests were re-administered to elicit any improvement in conceptual change and SPS.

Participants

The sample of the study consisted of 49 pre-service science teachers (aged 20 to 22 years) from a middle-sized public university in Turkey. The students, who were in the third year of their four-year program, were of average socioeconomic status and incomes. They had successfully passed a high-stakes nationwide examination and voluntarily chose this department. By this time, they had studied the subject of "gases and gas laws" in the 11th grade and then again in the first-year of their science education program. As the Turkish science curriculum follows a top–down model in curriculum development, all students take compulsory science courses in lower and upper secondary schools. They were initially introduced to gases and the related underlying gas concepts (*i.e.*, gas laws, kinetic theory, diffusion/ /effusion, ideal gases and gas mixtures) in 11th grade chemistry course. Additionally, in the first-year of the science education program, they attended General Chemistry I–II including such topics as structure of matter, solution chemistry, gases and gas laws, chemical bonding, mole and chemical calculations, periodic table, and redox.

A four-year-science teacher education program, which is an integrated framework of physics, chemistry, biology, earth science and astronomy, covers 240 European Credit Transfer System (ECTS)-180 ECTS for compulsory courses and 60 ECTS for elective courses. All Turkish science teacher education programs have to track the same syllabus of any compulsory course offered by Higher Education Council (Yüksek Öğretim Kurumu). These courses are labeled under four categories: subject matter knowledge (*i.e.*, General Chemistry I–II, Science Laboratory Practices I–II, Special Topics in Chemistry), pedagogical content knowledge (*e.g.*, Science Teaching Methods I–II), general pedagogy knowledge (*i.e.*, philosophy of education, sociology, guidance and counseling) and general cultural knowledge (*e.g.*, foreign language – English, German, French).

All the participants were currently enrolled in the "Science Laboratory Practices-I" course in which they actively implemented several tasks and experiments with gases. Before the teaching intervention, all official permissions were completed. In addition, the pre-service science teachers were informed about the teaching intervention and invited to sign a consent form. The first author informed them that they were not obliged to participate in the study and would not get any extra points for their participation. Furthermore, they could freely leave the study if they felt uncomfortable. Consequently, the current study evaluated and only reported data from the pre-service science teachers who had signed the consent form and participated voluntarily.

Teaching intervention

The subject of "Gases and gas laws" covers the effects of temperature, volume, pressure and mole on gases. The researchers developed the 5Es lesson plans and then sent them to a group of experts (four chemistry educators and one science educator) to ensure content validity. To assure further validity, the 5Es lesson plans and related guide materials were pilot-tested with 28 pre-service science teachers, who were not participants for the actual study. The reviews resulted in some minor revisions (*i.e.*, typographical errors and images). The first author firstly asked them to generate their own small groups of 3–4 and then carried out all teaching sessions in a science laboratory (a total of 8 class-hours–eight 50 min) for

both groups. Overall, the experimental group pursued the 5Es learning model, whilst the control one followed the existing instructions (see Appendices 2 and 3 of the Supplementary material).

In the experimental group, the worksheets purposed to revise and reinforce their gained knowledge by directly challenging the alternative conceptions 1, 3, 5–8 of gases and gas laws (see Table S-I). Furthermore, these worksheets requested them to use explicitly such SPS as observing, measuring, classifying, identifying variables, formulating hypotheses, interpreting data, defining operationally and doing experiments. Moreover, the analogy used in the current study intended to familiarize unfamiliar concepts by dealing with the alternative conceptions 5, 11 and 15 (see Table S-I). For example, a "sumo wrestler" analogy was used to make the relationship between the temperature and volume of a fixed quantity of gas familiar. Later, the pre-service science teachers were asked to compare analogue features (*i.e.*, sumo wrestling ring) with target ones (*e.g.*, Charles Gas Law, and the particulate nature of matter) *via* analogy mapping. Furthermore, it directly asked them to exploit "interpreting data" as an SPS. The computer animations helped them visualize sub-microscopic issues of movements of gas molecules and link macroscopic level with sub-microscopic one by handling the alternative conceptions 2, 4, 9–14 (see Table S-I). Hence, the computer animations required them to employ such SPS as identifying variables, defining operationally and formulating models. The 5Es learning model highlighted class/group discussion, therefore, the pre-service science teachers were encouraged to share their ideas/results with peers through real life examples and to negotiate the foregoing alternative conceptions. In addition, discussion processes engaged them in such SPS as communicating, predicting and inferring.

Lessons for the control group were comprised of existing laboratory activities (*e.g.*, experiments, lecture and question–answer, see Appendix 3 of the Supplementary material).

Instruments

To collect data, the researchers developed the gas laws test with 12 two-tier items. In developing the instrument, they firstly decided relevant concepts to ensure content validity. Later, they examined the literature to learn common alternative conceptions (see Table S-I) and wrote multiple-choice questions by taking these alternative conceptions into account.[20,21] All multiple-choice questions included one correct answer and four distracters including alternative conceptions. A multiple-choice question was the first-tier of the question, while the second-tier asked the pre-service science teachers to write down the reason for their selection.

A group of experts (three chemistry educators and two chemistry teachers) ensured face validity, readability and content validity of the gas laws test. The instrument was further validated when the participants in the pilot of the 5Es lesson plans (28 pre-service science teachers) were asked to read the gas laws test and depict any unclear point. Thereafter, they suggested some minor revisions (*i.e.*, typographical errors). Finally, the test was pilot-tested with 115 pre-service science teachers in the third-year of their four-year science education program, who were not participants of the actual study. The reliability coefficient for the gas laws test was found to be 0.603 (see Appendix 4 of the Supplementary material).

This sample question, which measured the relationship between the volume and temperature of a fixed quantity of gas (Charles Gas Law), took the following alternative conceptions into account: "An increase in the temperature does not change the volume of gas", "Changes in the pressure and volume affect the temperature of a compressed gas" and "Cold environment increases the volume of the balloon and decreases its pressure". In other words, related alternative conceptions led the researchers to develop and administer the gas laws test.

The researchers also used the science process skills test (SPST, with 25 multiple-choice and 11 open-ended questions).[35] Multiple-choice questions focused on recalling the SPS and could quickly be scored (time-efficient) by the participants. The open-ended questions, on the other hand, concentrated on their understanding of SPS, and the use of scientific language (*i.e.*, scientific terminology). Hence, the researchers were able to combine the advantages of multiple-choice and open-ended questions within the same instrument (see Appendix 5 at Supplementary material).

This sample question (Question 19) measured "formulating hypothesis and identifying variables (*e.g.*, independent, dependent and controlled variables)" of SPS with which students and pre-service teachers had difficulties.[28,29,32] That is, the SPST paid more attention to the SPS difficulties depicted by the relevant literature. The instruments were administered as pre-tests one week before the teaching intervention. After the teaching intervention, the same instruments were re-administered as post-tests. Furthermore, the researchers did not give any information about the data collection tools and their possible responses to the participants. For this reason, they did not know that the data collection tools would be employed as post-tests after the treatment. However, they may have considered their responses and discussed them with their peers. This may be seen as the effect(s) of the teaching intervention on building their own knowledge and facilitating their science learning.

Data analysis

In analyzing the gas laws test, the responses were ranked from the most scientifically accepted ones to scientifically incorrect ones. Given the framework of the expected responses and context of the current study, the researchers had made changes in the scoring criteria provided in the related literature.[20,21] That is, the first-tier of each item in the gas laws test was scored using the following criteria: "Correct option (4 points), incorrect option (one point), and blank (zero point)". The second-tier of each item in the gas laws test was assessed with the criteria: "sound understanding (8 points), partial understanding (6 points), partial understanding with alternative conception (2 points), and no understanding (zero point, see Table S-II for details)".[20,21] To highlight their explanations in the second-tier of each item, the researchers decided to give higher points to the open-ended questions and calculated total scores to run statistical and inferential analysis.[20,21]

The responses of pre-service science teachers to the multiple-choice questions in the SPST were scored with either one point (correct response) or zero point (incorrect response). The open-ended questions in the SPST were analyzed through rubrics adapted from related literature (see Table S-III for a sample rubric).[36] Since the one-sample Kolmogorov Smirnov test did not show a normal distribution of the data, this study employed non-parametric statistical methods (*i.e.*, the Mann Whitney U test and the Wilcoxon signed rank test).

RESULTS AND DISCUSSION

Results from the gas laws test

As seen from Table I, there was no statistically significant difference between the mean scores of the experimental and control groups in the pre-gas laws test ($U = 289.000$, $p > 0.05$, $\eta^2 = 0.13$). Their rank average values showed that the pre-gas laws test scores were similar. In the post-gas laws test, the Mann–Whitney U test indicated a statistically significant difference between the groups ($U = 80.500$, $p < 0.05$, $\eta^2 = 0.66$) in favor of the experimental group. This

revealed that the 5Es learning model assisted the pre-service science teachers in improving their conceptual understanding of gases and gas laws better than the existing method. The closer the η^2 value is to 1, the more the experimental group out-performs the control group. The results of partial eta squared (η^2) indicated a small-size effect for the pre-gas laws test (0.13) and a large-size effect for the post-gas laws test (0.66).

TABLE I. The results of the Mann–Whitney U test for the pre- and post-gas laws tests; CG: control group, EG: experimental group; note: U means a derived statistic to compare a specific value in a Mann–Whitney distribution table for statistical significance

Group	Type of test	N	Rank average	Rank total	U	p	η^2
CG	Pre-test	25	18.15	614.00	289.000	0.82	0.13
EG		24	17.46	611.00			
CG	Post-test	25	20.86	540.50	80.500	**0.00**	0.66
EG		24	34.52	828.50			

As can be seen from Table II, both groups had statistically significant differences between their mean scores in the pre- and post-gas laws test in favor of the post-gas laws test (control group; $z = 3.05$, $p < 0.05$, $\eta^2 = 0.61$; experimental group; $z = 3.57$, $p < 0.05$, $\eta^2 = 0.73$). Rank averages of the pre- and post-gas laws test scores showed positive ranks in favor of the post ones. The results of partial eta squared (η^2) revealed large-size effects for both the control (0.61) and experimental groups (0.73). The partial eta squared (η^2) values denote that the teaching interventions in the experimental and control groups were effective in facilitating the conceptual understanding of pre-service science teachers (*e.g.*, a medium-size effect for the control group and, a large-size effect for the experimental group). However, as compared with the existing instruction, the 5Es learning model was more efficient. This may stem from macroscopic and submicroscopic representations in the computer animations. Furthermore, the experimental group's engagements with the relational variables and graphics (*i.e.*, the effects of temperature, volume, pressure and mole on gases) may have resulted in their improved performances. In addition, having yielded any mathematical equation between the relational variables seems to have evolved their conceptions of symbolic representation(s) of gases.

Although not as pronounced as the experimental group, the control group did show improvements after participating in regular (existing) teaching methods. The existing experiments and lecturing might have allowed them to imagine mentally complex/abstract dynamic processes at the sub-microscopic level and molecular behaviors of gases. Furthermore, medium-size effects in the conceptual understanding of the control group may have come from the question–answer processes and feedbacks in their regular learning. Moreover, the fact that the existing instruction somehow resulted in remedying some of the alternative con-

ceptions in the pre-test may stem from the engagement of the control group with the regular experiments (see Table S-IV).

TABLE II. The results of Wilcoxon signed rank test for the pre- and post-gas laws tests; CG: control group, EG: experimental group; the z value is compared with the critical z value to determine the null or research hypothesis

Group	Post-test–Pre-test	N	Rank average	Rank total	z^a	p	η^2
CG	Negative rank	4	8.42	26.50	3.05	**0.00**	0.61
	Positive rank	21	16.74	298.50			
	Equal	–	–	–			
EG	Negative rank	–	–	–	3.57	**0.00**	0.73
	Positive rank	24	12.50	300.00			
	Equal	–	–	–			

[a]Based on negative ranking

Percentages of the alternative conceptions of the pre-service science teachers of gases and gas laws were calculated through their responses to the pre- and post-gas laws test. As observed in Table S-IV, the pre-gas laws test drew out 9 alternative conceptions for the control group and 6 alternative conceptions for the experimental group. After the treatments in both groups, the control and experimental groups accomplished positive conceptual change for 8 and 6 alternative conceptions, respectively. Furthermore, the control group showed one negative conceptual change for the ninth alternative conception and one neutral conceptual change for the fourth alternative conception. This means that the experimental group demonstrated a better performance in achieving conceptual change than did the control one. For example, the percentages of the experimental and control groups holding the first alternative conception were 40 and 48 for the pre-gas laws test; and 13 and 32 for the post-one, respectively. Decreases in the post-test percentages of the experimental and control groups showed that the students remedied their alternative conceptions after the teaching intervention. In this case, the positive conceptual change (CC) was indicated with (+). For instance, the conceptual change rates of the control and experimental groups for the first alternative conception (+8 and +27, respectively – see Table S-IV) mean that the teaching intervention in the experimental group had a greater impact on remedying the first alternative conception than that in the control one. On the other hand, the control group's percentages of the ninth alternative conception (4 % in the pre-test and 8 % in the post-test) showed an increase in their post-test percentage. In this case, this negative CC was signaled with (–). For the ninth alternative conception, the control group revealed a negative conceptual change (–4).

The results from the post-gas laws test showed that the 5Es learning model helped the pre-service science teachers to overcome their alternative conceptions and significantly improved their conceptual understanding of the subject of "gases and gas laws". Phrased differently, the 5Es learning model, which took

common alternative conceptions of 'gases and gas laws' into consideration, seems to have enhanced the pre-service science teachers' learning capabilities[20,28] and to have resulted in a better understanding of scientific concepts.[12]

Even through the experimental and control groups' alternative conceptions of "gases and gas laws" decreased in the post-gas laws test, the experimental group performed better in remedying relevant alternative conceptions than did the control one. For instance, the computer animations and experimental activities, which afforded the pre-service science teachers to imagine Gay–Lussac Gas Law at the sub-microscopic level and its processes,[16] overcame the third alternative conception (see Table S-IV). Similarly, the fact that the computer animations, experimental activities and analogy explicitly challenged such alternative conceptions as "Students possess pitfalls at understanding relationships amongst pressure, temperature, volume, and mole" seems to have somewhat overcome the first four alternative conceptions (see Table S-IV). The analogy and experimental activities handling the fifth alternative conception (see Table S-IV) may have dealt with their misunderstanding of the particulate nature of matter (*i.e.*, gas molecules expand or shrink when heated or cooled, respectively).[37] Similarly, the worksheets and computer animations clearly seem to have remedied the seventh alternative conception since the 5Es learning model took common alternative conceptions into account. However, the teaching interventions in the experimental and control groups were unable to remedy completely the first alternative conception of "gases and gas laws".

Results from the science process skills test (SPST)

The results of the pre- and post-SPST are given in Table III.

TABLE III. The results of Mann–Whitney U test for the pre- and post- SPST; *U* means a derived statistic to compare a specific value in a Mann–Whitney distribution table for statistical significance

Group	Type of test	Rank average	Rank total	U	p	η^2
Control group	Pre-test	23.08	577	252	0.33	0.12
Experimental group		27	648			
Control group	Post-test	13.82	345	20.5	0.00	0.79
Experimental group		36.65	879			

As seen from Table III, there was no statistically significant difference between the mean scores of the pre-SPST of the experimental and control groups ($p > 0.05$). This means that the experimental and control groups were very similar to each other. Furthermore, there was a statistically significant difference between the mean scores of the post-SPST in favor of the experimental group ($p < 0.05$). This showed that the 5Es learning model was more effective in improving their SPS than the existing instruction. The results of partial eta squared

(η^2) indicated a small-size effect for the pre-SPST (0.12) and a large-size effect for the post-SPST (0.79). The results of Wilcoxon signed rank test for the pre- and post-SPST are presented in Table IV.

TABLE IV. The results of Wilcoxon signed rank test for the SPST; the z value is compared with the critical z value to determine the null or research hypothesis

Group	Post-test–Pre-test	N	Rank average	z^*	p	η^2
Control Group	Negative rank	2	3.25			
	Positive rank	23	13.84	3.19	0.00	0.53
	Equal	–	–			
Experimental Group	Negative rank	0	.00			
	Positive rank	24	12.50	4.29	0.00	0.88
	Equal	–	–			

[a]Based on negative ranking

As observed in Table IV, the rank averages of the pre- and post-SPST scores of the experimental and control groups revealed positive ranks in favor of the post-SPST ones ($p < 0.05$). That is, both groups had changes in the SPS after the treatment. The results of the partial eta squared (η^2) indicated a medium-size effect for the control group (0.53) and a large-size effect for the experimental group (0.88).

The results indicated that the 5Es learning model was also more effective in improving the SPS scores of pre-service science teachers. This result complies with related studies.[28,29] The SPS scores of the control group, which were significantly lower than those of the experimental group, supported the idea that concept-related experiments are insufficient in improving the SPS levels of students. These findings provide further evidence that an interaction between content knowledge (*e.g.*, gases and gas laws) and SPS not only improve SPS[25,28,29] but also make abstract chemistry concepts more meaningful.

The partial eta squared (η^2) values revealed that the teaching interventions in the experimental and control groups were efficient in developing their SPS (*e.g.*, a medium-size effect for the control group and a large-size effect for the experimental group). However, as compared with the existing instruction, the 5Es learning model was more effective. This may stem from the engagements of the experimental group with the relational variables, graphics (*i.e.*, the effects of temperature, volume, pressure and mole on gases) and computer animations. Furthermore, a medium-size effect in SPS of the control group may arise from the question–answer processes and feedbacks in their regular learning (see Table S-V for the descriptive parameters).

CONCLUSIONS

The present study revealed that the 5Es learning model resulted in better gains in the conceptions of pre-service science teachers of "gases and gas laws"

and improved their SPS. This means that pedagogical interlinks amongst conceptual change methods (*e.g.*, worksheets, computer animations, and analogies), content knowledge (*e.g.*, gases and gas laws) and SPS increase their learning capacities of conceptual understanding and SPS.

The study found, however, that there were alternative conceptions that were resistant to change in both groups. This implies that the 5Es learning model and existing instruction seem to have mainly influenced soft-core alternative conceptions. Fortunately, it appears that neither the 5Es learning model nor the existing instruction resulted in any new alternative conception after the teaching intervention. This may come from the 5Es learning model directly handling common alternative conceptions of "gases and gas laws".

Although the existing instruction did not concentrate specifically on common alternative conceptions of "gases and gas laws", the alternative conceptions of pre-service teachers were somewhat reduced and showed improvements. This may be because the lecturer might intuitively address these alternative conceptions during the question/answer sessions. Phrased differently, the lecturer who taught the subject to both the experimental and control groups may have transferred her awareness of common alternative conceptions to the existing instruction (control group). This may be seen as an uncontrolled variable (limitation) of the current study.

Even though the pre-service science teachers held some common alternative conceptions reported by the related literature (see Table S-I), the current study elicited several new alternative conceptions (*i.e.*, the first, fourth, sixth and tenth alternative conceptions – see Table SI-V). This may stem from their pre-existing experiences or learning/class cultures or contextual differences in various countries.

Since the 5Es learning model engaged the pre-service science teachers in actively building their own understanding, they should be confronted with possible alternative approaches/pedagogies suggested by the Turkish science curriculum. Future studies may investigate how student-generated-animations influence their imagination of macroscopic, submicroscopic and symbolic representations. The current study recommends that the 5Es learning model be tested with a large sample size throughout a long-term teaching intervention. In addition, to challenge effectively alternative conceptions of students, future studies should exploit alternative conceptions elicited in the pre-test/treatment rather than common ones reported in the literature.

SUPPLEMENTARY MATERIAL

Additional analytical and crystallographic data are available electronically from http://www.shd.org.rs/JSCS/, or from the corresponding author on request.

И З В О Д

ЕФЕКТИ 5Es МОДЕЛА УЧЕЊА НА КОНЦЕПТУАЛНО РАЗУМЕВАЊЕ И НАУЧНЕ
ВЕШТИНЕ БУДУЋИХ НАСТАВНИКА НАУКЕ: СЛУЧАЈ ГАСОВА И ГАСНИХ ЗАКОНА

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Циљ овог истраживања био је испитивање ефеката примене 5Es модела учења (*енгл.*, engage-explore-explain-elaborate-evaluate) на концептуално разумевање и научне веш-тине будућих наставника науке у вези с гасовима и гасним законима. Узорком истра-живања обухваћено је 49 студената, будућих наставника науке, уписаних на курс *Научне лабораторијске праксе - I*, у оквиру катедре за научно образовање на Турском државном универзитету. Применом квази-експеримента (дизајн који је обухватио иницијално и финално тестирање), експериментална група била је изложена 5Es моделу учења с раз-личитим концептуалним променама метода/техника (на пример, радни листови, комп-јутерске анимације, аналогије и експерименти). Контролна група била је подучавана кроз уобичајену наставу (на пример, експерименти, предавања и одговарање на питања). Подаци су прикупљени применом тестова (тест који се односио на гасне законе и тест у вези с научним вештинама). Резултати парцијалне квадриране ете (η^2) указали су на велике ефекте за контролну (0,61) и експерименталну групу (0,73). Модел учења 5Es показао се ефикаснијим од постојеће наставе у превазилажењу алтернативних кон-цепата будућих наставника науке у вези с гасовима и гасним законима, као и у унапре-ђивању нивоа њихових научних вештина. Препорука изведеног истраживања је да се модел учења 5Es тестира на већем узорку укључујући дужи временски период интер-венције.

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REFERENCES

1. M. G. Séré, *Eur. J. Sci. Educ.* **8** (1986) 413 (https://doi.org/10.1080/0140528860080408)
2. R. Stavy, *Int. J. Sci. Educ.* **10** (1988) 553 (https://doi.org/10.1080/0950069880100508)
3. J. L. Chiu, C. J. DeJaegher, J. Chao, *Comput. Educ.* **85** (2015) 59 (https://doi.org/10.1016/j.compedu.2015.02.007)
4. B. Coştu, *J. Sci. Educ. Tech.* **16** (2007) 379 (https://doi.org/10.1007/s10956-007-9069-z)
5. H. Lin, H. Cheng, F. Lawrenz, *J. Chem. Educ.* **77** (2000) 235 (http://dx.doi.org/10.1021/ed077p235)
6. M. B. Nakhleh, R. C. Mitchell, *J. Chem. Educ.* **70** (1993) 190 (http://dx.doi.org/10.1021/ed070p190)
7. E. Yalçınkaya, Y. Boz, *Chem. Educ. Res. Prac.* **16** (2005) 104 (http://dx.doi.org/10.1039/c4rp00156g)
8. N. Azizoğlu, Ö. Geban, *Balıkesir Uni. Sci. Inst. J.* **6** (2004) 73
9. A. Gürses, Ç. Doğar, M. Yalçın, N. Canpolat, in *Proceedings of the Fifth National Science and Mathematics Education Congress*, Ankara, Turkey, 2002
10. C. Nakiboğlu, R. Özkılıç Arık, *Yeditepe Uni. J. Educ.* **1** (2006) 1
11. C. H. Kautz, P. R. L. Heron, M. E. Loverude, L. C. McDermott, *Am. J. Phys.* **73** (2005) 1055 (https://doi.org/10.1119/1.2049286)
12. P. S. Çetin, E. Kaya, Ö. Geban, *J. Sci. Educ. Tech.* **18** (2009) 130 (https://doi.org/10.1007/s10956-008-9138-y)

13. E. Şenocak, Y. Taşkesenligil, M. Sözbilir, *Res. Sci. Educ.* **37** (2007) 279 (https://doi.org/10.1007/s11165-006-9026-5)
14. L. I. Robins, G. Villagomez, D. Dockter, E. Christopher, C. Ortiz, C. Passmore, M. H. Smith, *Sci. Teach.* **76** (2009) 35
15. S. Abdullah, A. Shariff, *Eurasia J. Math. Sci. Tech. Educ.* **4** (2008) 387 (https://doi.org/10.12973/ejmste/75365)
16. X. Liu, *J. Sci. Educ. Tech.* **15** (2006) 89 (https://doi.org/10.1007/s10956-006-0359-7)
17. M. Aydeniz, A. Pabuccu, P. S. Cetin, E. Kaya, *Int. J. Sci. Math. Educ.* **10** (2012) 1303 (https://doi.org/10.1007/s10763-012-9336-1)
18. J. Chao, J. L. Chiu, C. J. DeJaegher, E. A. Pan, *J. Sci. Educ. Tech.* **25** (2016) 16 (https://doi.org/10.1007/s10956-015-9574-4)
19. A. Pabuccu, S. Erduran, *Chem. Educ. Res. Prac.* **17** (2016) 523 (http://dx.doi.org/10.1039/C6RP00011H)
20. F. Karslı, M. Çalık, *Asian J. Chem.* **23** (2012) 485
21. S. E. Nas, M. Calik, S. Cepni, *Ener. Educ. Sci. Tech., B* **4** (2012) 177
22. C. C. Dawson, *PhD Thesis*, University of Northern Colorado, USA, 1999
23. K. E. Colley, *Sci. Act.* **43** (2006) 26 (https://doi.org/10.3200/SATS.43.1.26-33)
24. P. Rillero, *Sci. Act.* **35** (1998) 3 (https://doi.org/10.1080/00368129809600910)
25. L. C. Scharmann, *J. Res. Sci. Teach.* **26** (1989) 715 (https://doi.org/10.1002/tea.3660260807)
26. W. Harlen, *Assess. Educ.* **6** (1999) 129 (https://doi.org/10.1080/09695949993044)
27. C. Keil, J. Haney, J. Zoffel, *Elec. J. Sci. Educ.* **13** (2009) 1
28. F. Karslı, A. Ayas, *J. Comput. Educ. Res.* **1** (2013a) 1
29. M. Yildirim, M. Çalik, H. Özmen, *Int. J. Env. Sci. Educ.* **11** (2016) 6518.
30. S. P. Norris, L. M. Phillips, *Sci. Educ.* **87** (2003) 224 (https://doi.org/10.1002/sce.10066)
31. V. M. Chabalengula, F. Mumba, S. Mbewe, *Eurasia J. Math. Sci. Tech. Educ.* **8** (2012) 167 (https://doi.org/10.12973/eurasia.2012.832a)
32. S. Mbewe, V. M. Chabalengula, F. Mumba, *Prob. Educ. 21st Century* **22** (2010) 76
33. B. Namdar, M. Kucuk, *J. Sci. Teach. Educ.* **29** (2018) 468 (https://doi.org/10.1080/1046560X.2018.1469188)
34. R. W. Bybee, in *Proceedings of Scientific Literacy, An International Symposium*, Institut für die Pädagogik der Naturwissenschaften (IPN), Kiel, Germany, 1997, pp. 37–68
35. F. Karslı, A. Ayas, *J. Turkish Sci. Educ.* **10** (2013b) 67
36. B. K. Temiz, *Assessing Science Process Skills in Physics Teaching*, Unpublished Doctorate Thesis, University of Gazi, 2007
37. A. Ayas, H. Özmen, M. Çalık, *Int. J. Sci. Math. Educ.* **8** (2010) 165 (https://doi.org/10.1007/s10763-009-9167-x)
38. R. Osborne, M. C. Wittrock. *Sci. Educ.* **67** (1983) 4 (https://doi.org/10.1002/sce.3730670406).