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Online activity practices based on common knowledge constructing model: Example of radioactivity topic

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Highlights

- Conducting online experiment simulations and discussions on socio-scientific dilemmas helped students concretize their concepts of radioactivity.
- CKCM has a positive impact on science teacher students' conceptual understanding of radioactivity topic.
- Online activities can provide active learning to science teacher students despite distance learning.

Article Info: Research Article

Keywords: *Online activities, conceptual understanding, Common Knowledge Construction Model (CKCM), radioactivity.*

Abstract

The aim of this study was to examine the effect of the Common Knowledge Construction Model (CKCM) on the conceptual understanding of science teacher students about Radioactivity. CKCM was used. In order for the students to adapt the radioactivity subject, which they see as difficult and abstract, to daily life by knowledge structuring. This study was carried out with 48 students studying in the second year of science education at a public university in the western region. The research employed pretest-posttest control group random design. The Radioactivity Concept Test (RCT) with 2 phases consisting 23 multiple- choice items were used as data collection tools in the research. After the tests were applied as a pilot study to 124 students, it was used with the participants of the study after the necessary validity and reliability studies were carried out. The KR20 reliability coefficient obtained from the sample data was calculated as 0.74. In the study, experimental and control groups were formed by random assignment. While the traditional lecture method was applied to the control group, the CKCM was applied to the experimental group. When the concept test data were analyzed with the SPSS 24 package program, it was determined that the experimental group were more successful than the control group. determined that the increase in correct answers in the post-test of the experimental group was higher than that of the control group.

1. Introduction

Society and social life are directly or indirectly influenced by advancements in science and technology. Technological developments have brought products to society based on knowledge derived from scientific studies. However, while these products have facilitated human lives, they have also given rise to new problems. Nuclear power plants, for instance, can provide cheap and powerful energy to

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meet a significant portion of society's energy needs. Nevertheless, the radiation that could result from a nuclear accident poses a significant threat to human health. As a result, both positive and negative views exist regarding nuclear power plants, both in our country and globally. This example of nuclear energy demonstrates how science directly impacts social life. Concepts associated with science and technology, such as global warming, genetic engineering, and nuclear energy use, have recently drawn the attention of many science education experts. Socio-scientific issues are the terms used to define these social dilemmas (Atasoy, 2018; Bell & Lederman, 2003;Kolsto, 2001; Sadler, 2004).

Being conscious of socio-scientific issues has led to the establishment of new objectives in education, aiming to adapt to a changing world and promote such progress. One of these objectives is to raise individuals who possess scientific literacy (Ministry of National Education [MEB], 2004). However, nuclear physics is an essential part of socio-scientific debates, influencing numerous phenomena that affect our lives. Ağbulut (2015), who worked on radioactivity, stated that radiation exists in many aspects of our daily lives. Due to students' preconceptions about basic physics and encountering these concepts frequently in everyday life, there is potential for misconceptions to form. The subject of this study is radioactivity, which is currently perceived as a difficult topic by students due to its abstract nature and involved concepts. In additionally the traditional teaching method It is argued that the discrepancy between success at traditional context and failure in conceptual questions stems from the ineffectiveness of traditional instruction methods in terms of contribution to conceptual learning.

In this study, the CKCM was employed to eliminate misconceptions. The reason for using the CKCM is that it serves as an instructional model where students can relate concepts to everyday life, eradicate misconceptions, and acquire more information about socio-scientific issues. Another reason is Students who are not successful can raise their achievement levels by being encouraged to actively participate in the activities during the lesson (Çirkinoğlu Şekercioğlu, 2023). Within this scope, this study aims to introduce online teaching activities based on the CKCM for the instruction of Radioactivity. The RCT was applied to measure the impact of these CKCM-based activities on students' conceptual understanding.

2. Literature

The Common Knowledge Construction Model (CKCM)

In 1998, Ebenezer and Connor introduced a new theory. They aimed to achieve several objectives through this theory. Firstly, they intended to make students aware of their misconceptions by utilizing various meanings of natural and social events. Additionally, they sought to promote scientific thinking by eliminating these misconceptions through questioning (Ebenezer et al., 2004). To this end, students are expected to comprehend and interpret socio-scientific issues in everyday life, as well as to challenge and modify their existing misconceptions through self-questioning, fostering scientific thinking. In their research, Çavuş-Güngören and Hamzaoğlu (2020) received the opinions of prospective teachers who prepared lesson plans for the nature of science about CKCM. 25 teacher candidates participated in the study and the data of the study were collected through open-ended questions and semi-structured interviews about CKCM. As a result of the study, prospective teachers evaluated CKM positively about the student's ability to learn by doing and experiencing and associating old and new knowledge. They negatively evaluated situations such as time management and individual differences making the application difficult.

In formulating this theory, Ebenezer and Connor (1998) were influenced by various ideas and perspectives, including Marton's "Learning Variation Theory", Piaget's "conceptual change studies", Vygotsky's "Zone of Proximal Development within a social context", Bruner's view of "language as part of the cultural symbolic system", and Doll's "Scientific Discourse" (Biernacka, 2006). The CKCM is based on several approaches, including the structuralist learning theory, social learning, conceptual change approach, and phenomenography. The CKCM comprises four steps, which are expected to be implemented during the teaching process: Exploration and Categorization, Construction and Negotiation, Extension and Transfer, and Reflection and Assessment.

Step-I: Exploration and Categorization

The objective of this stage is to identify students' prior knowledge. For this purpose, students are shown visuals and videos related to the topic, and questions are directed to them. This process helps to capture students' attention, and their responses are used to form phenomenographic categories. The responses are not labeled as right or wrong. The goal of this step is to determine what kind of prior knowledge students have regarding the natural world (Ebenezer et al., 2004). The reason of the use videos on this stage is to ensure that students' knowledge is permanent (Tecimer & Barış, 2018).

Step-II: Construction and Negotiation

In the Construction and Negotiation stage, students engage with the nature of science. It is where their scientific knowledge is blended with the nature of science. In other words, students experience the stages of scientific work during this phase. They also compare their misconceptions with the correct concepts.

Step-III: Extension and Transfer

The Extension and Transfer stage is when students become aware of their misconceptions, and after experiencing how scientific knowledge is formed through scientific work, they relate and interpret new knowledge with socio-techno-economic-environmental contexts. Students are expected to make interpretations based on the new knowledge they have acquired about socio-scientific issues.

Step-IV: Reflection and Assessment

The Reflection and Assessment stage is where students structure the topic by using alternative assessment techniques, and their learning levels are determined. Teachers can assess the students' understanding of the subject using the assessment techniques they employ (Biernacka, 2006; Ebenezer et al., 2010).

Prediction-Explanation-Observation-Explanation (PEOE) Method

The constructionist learning theory employs the Prediction-Observation-Explanation (POE) method. This method is based on students making predictions before an event or activity, followed by observing the event and comparing it with their predictions (White, 1992). The Prediction-Explanation-Observation-Explanation (PEOE) method expands this strategy by adding a fourth step, where students are expected to explain their predictions (Özden, 2019). Tekin (2008) stated that the PEOE strategy is a method that enables students to be interested and active in the course rather than remaining passive in the learning process. In addition, he commented that it is a method that enables students not only to repeat information, but also to think about that information and explain it with their own knowledge.

Science-Technology-Society-Environment (STSE)

Science-Technology-Society interactions was interested some of western countries at 70’s (Aikenhead, 2003; Solomon & Aikenhead, 1994;Yager, 1996;Yalaki, 2014). The FTT movement emerged with the idea that traditional science education cannot meet the needs of societies as science and technology affect human life and societies more in our age. Science, Technology, Society, Environment (FTTS) education, which is a type of this movement in which the impact of scientific and technological developments on the environment is more emphasized, has gained importance in science education in the last 30 years and has influenced the science curricula of many countries (Yalaki,2014). In parallel with these developments, FTTÇ education was included in the science teaching programs prepared in Turkey in 2005 and 2013 (M.E.B., 2005, 2013). Students use critical thinking while revealing the relationships between science-technology-society-environment in problem-solving processes (Karabal, 2017).

3. Method

In this section, all the steps of the research are detailed, including the research objective, the creation and implementation stages of the tests and activities used in the study.

3.1 Research Design

This research was conducted with second-year students majoring in Science Education at the education faculty which at west region of the Türkiye. The aim of the study was to investigate the impact of the CKCM on students' achievement compared to the traditional method. The real experimental method with the "pretest-posttest control group random design" model was used in the research. In this model, after groups are formed by random assignment, pre-experiment measurements are made to the both groups with RCT. After the measurement CKCM used for experimental group with teaching materials and traditional model used for control group without materials. At the end of the teaching practice, post-test measurements are made to the both groups. The teaching practice took 4 weeks for both groups. And the teaching was online because of the Covid 19 pandemic. The teaching practice shown in Table 1.

Table 1:
The teaching practice.

Groups	Pre test	Teaching practice	Post test
E.G	RCT	CKCM	RCT
E.G.	RCT	Posters, videos and worksheets	RCT
E.G.	RCT	Experiment simulations	RCT
E.G	RCT	PEOE Method and online evaluation activities	RCT
C.G.	RCT	Traditional Method	RCT

E.G.: Experimental Group
C.G.: Control Group

Having pre-tests in the model allows the similarities of the groups to be known before the experiment and the post-test results to be evaluated accordingly. The fact that the measurements before the experiment are significantly different from each other makes the interpretation of comparisons difficult (Karasar, 2011; Karaburç & Tunç, 2017). But in this research the pre-test results are not significantly different. This result shown that the groups are chosen randomly and both groups were compared, it was determined that there was no significant difference between the experimental group and the control group in terms of conceptual understanding of radioactivity [t=1.275, p>.05]. The pre-test result shown in Table 1.

Table 1:
t-test results for pre-test.

					Levene test				
	Groups	N	Mean	SS	F	p	t	Sd.	p
Pre-Test	Experimental group	24	27.13	4.47	7.06	.011	1.275	38.43	0.210*
	Control Group	24	29.33	7.21					

According to this result, it can be interpreted that the experimental and control groups had similar alternative concepts and prior knowledge about radioactivity. The fact that the prior knowledge of the students is close to each other is that although the subject of radioactivity is not included in the lesson plans very often, they are frequently encountered concepts in daily life. The fact that not too many questions are asked about radioactivity in the university entrance exam held by OSYM also gives the result that this subject is ineffective in the curriculum (Bakaç & Taşoğlu, 2011).

3.2 Data Collection Tools

This researchers aim is identify the misconceptions of science teacher candidates regarding Radioactivity topic. For this reason, the Misconception identification test was used. The test name is RCT.

3.3. Radioactivity Concept Test (RCT)

In order to determine the misconceptions of science teacher candidates about nuclear physics, Yumuşak (2013) developed a two-stage "Misconception Detection Test (MDT)" for his study. The test chosen as a two phase. The reason why the test was chosen in two stages is that multiple choice tests are used in the studies to measure the knowledge levels of the students. However, in these tests, students have the possibility of answering the question correctly even if they do not know the answer. Two-stage tests were developed in order to reduce the negative aspects of multiple-choice tests (Karataş, et al., 2003). However, in original test didn't have items about "isotope, binding energy, natural and unnatural radioactivity" concepts. That's why the researchers add items about these concepts and named the tests as "Radioactivity Concept Test (RCT)" used in research. Table 2 shows a comparison of RCT and MDT concepts.

Table 2:

Comparison of RCT and MDT concepts

Concepts	MDT item number/s	RCT item number/s
Binding energy	-	1,6
Isotope	-	2,3
radioactive material	1,2,5,8,10	8,9,11,15
Radioactivity	12	4,5,7
Radiation	4,11	14,16
Nuclear reactions	7,16	13
Half-Life	9	1,12
Alfa Decay	3,13	17,18
Beta Decay	6	-
Gamma Decay	14,15	19,20
Fission	18	21,23
Fusion	17	22

After adding items, the test applied to 124 students who get the radioactivity unit at Physic III class as a pilot study. After the applying test the item analyses and reliability analyze is measured by the researchers.

RCT is a two-phase test. In the first phase, students answer the item as "true or false". In the second phase, the student chooses the correct reason for the first phase. The scoring system of the two-stage test is as follows; if the student chose the correct answer for the first phase and second phase it is 3 points. If first phase is false but second phase is correct it is 2 points. If the first one is correct but second phase is false it is 1 point. If both of them are false it is 0 point (Karatas et al., 2003).

3.4. Material development

In this research some materials were used in accordance with CKCM. These materials are poster, videos, worksheets, experiment simulations, online evaluation activities.

Some materials developed by researchers (worksheets, poster, evaluation activities, lecture presentation).

Worksheet

The created worksheet aimed to make students aware of their misconceptions. Additionally, since it was not possible to bring posters and visuals to the classroom due to remote education, these materials were included in the worksheet. Students were asked to fill out the worksheet accordingly. In addition, worksheets are important tools that help students make sense of their knowledge in their own minds (Özmen & Yıldırım, 2005). When the worksheet developed benefited from misconceptions about radioactivity in literature. Additionally, researcher attention to use PEOE method in worksheet.

Poster

Poster was developed to take the students pre- knowledges. For this reason, the pictures about radioactivity, nuclear power plants, radiation, radiocarbon dating and the results of nuclear bombs added and under the pictures researcher asked "what does the photo above remind you of? Can you relate these photos with radioactivity?" and given the space for answers. The poster shown at Figure 1.

Fig.1. Poster shown to students for the exploring and categorizing phase

Experiment Simulations

In this research experiment simulations used because the radioactivity topic is not suitable for apply experiment in real life. Online simulation experiments on alpha and beta decays, as well as fission events, were implemented to students using the website http://phet.colorado.edu/tr/ .

Online Evaluation Activities

In this research alternative assessment methods were used to determine students' level of learning on the topic. For this purpose, activities were created on the website https://wordwall.net. The Wordwall application can be used both interactively and in the form of printable activities in the classroom. In addition, prepared activities and tests can be given as homework by the teacher, so that they can be applied individually by students outside the classroom environment (Koç, 2023). Students were asked to match the contents in the evaluation activities prepared by adding content to the site wordwall.com, which has ready-made templates. The misconceptions about radioactivity in literature was used while the activities were created.

3.5. Study Group

The sample of the study consisted of second-year students who took the Physics 3 course in the Department of Science Education at a public university in the western region during the 2020-2021 academic year. For this study, participants were randomly assigned. The experimental group and control groups number of students participating in this research is given in Table 3.

Table 3.
Number of students.

	Experimental group	**Control Group**	**Total**
Women	21	20	41
Men	3	4	7
Total	24	24	48

3.6. Data Analysis

After administering the RCT, the obtained data was analyzed as follows:

• The pre-test and post-test mean scores of the experimental and control groups were compared.

• To compare the pre-test and post-test scores of the experimental and control groups, independent samples t-tests were conducted using SPSS 26 statistical software.
• Cohen's d value was calculated to measure the effect size.

3.7. Validity and Reliability

To assess the reliability of the RCT, a pilot study was conducted with 124 students who had previously taken a Radioactivity topic with Physic III class. The KR20 reliability coefficient for the 23-item test was calculated by the researcher as 0.74. The KR20 value obtained for all items indicates the total reliability of the test, and the generally accepted threshold for this value is 0.7 or higher (Kılıç, 2016). For the validity analysis the item difficulty index and item discrimination index was calculated by researcher and its show in Table 4.

Table 4.
Radioactivity concept test item difficulty and item discrimination index.

	Phase One		**Phase Two**	
Number of Items	**Pj**	**r**	Pj	**r**
1	,59	,21	,60	,51
2	,60	,48	,51	,51
3	,86	,54	,81	,21
4	,51	,85	,81	,79
5	,56	,64	,52	,27
6	,75	,33	,21	,21
7	,86	,24	,56	,67
8	,60	,60	,54	,48
9	,52	,30	,32	,72
10	,56	,36	,59	,61
11	,46	,27	,35	,57
12	,83	,21	,21	,21
13	,49	,54	,35	,36
14	,59	,36	,49	,36
15	,38	,24	,38	,24
16	,67	,20	,63	,24
17	,63	,30	,56	,54
18	,51	,57	,46	,79
19	,41	,45	,35	,79
20	,48	,57	,44	,61
21	,63	,57	,60	,27
22	,41	,72	,25	,57
23	,46	,33	,32	,54

Pj: Item difficulty index
r: Item discrimination index
Item difficulty index was calculated for the first and second stages of the RCT by the researchers. Item analysis is performed to determine whether test items are effective in differentiating between students who know and do not know the subject matter (Yumuşak, 2013). The criteria to be considered when evaluating the item difficulty index and item discrimination index are as follows: if the discrimination index is 0.40 or higher, the item is very good and does not need to be corrected; If it is between 0.30–0.40, it is good and does not need to be corrected; If it is between 0.20 and 0.30, the substance can be used as is or changed when necessary; If the value is less than 0.20, the substance should not be used or should be rearranged. Items with zero or negative discrimination are not included in the test (Atasoy, 2018; Yumuşak 2013)

3.8. Research Procedure

In this study, the impact of the CKCM on the conceptual understanding of second-year students majoring in Science Education regarding the topic of radioactivity was investigated. The research was

conducted using a random design with pre-test-post-test control group. Both groups were administered the Radioactivity Concept Test before and after the instruction.
The RCT was prepared as a 2-stage test through an online survey platform.

3.9. Implementation of Activities

The activities used in this study were prepared to be suitable for distance education. Distance education, in its most general definition, is accepted as a form of education in which students and teachers remain physically separated (Kırmacı, et al., 2022). Therefore, various materials, such as worksheets, posters, videos, presentation slides, simulation experiments, and online activities, were developed and implemented online to support the different stages of the CKCM.

Activities for Exploration and Categorization Stage
The purpose of the Exploration and Categorization stage, which is the first step of the CKCM, is to determine what kind of prior knowledge students have regarding the natural world (Ebenezer et al., 2004). For this stage, the poster and visuals shown to the students were included in the worksheet. The poster and videos prepared by the researcher provided students with preliminary information about the concepts of fission, fusion, radiation, half-life, and nuclear energy.

Activities for Structuring and Negotiating Stage
During the Structuring and Negotiating stage, students engage with the nature of science, where their scientific knowledge is harmonized with the principles of science. In this stage the poster used thus students experience the stages of scientific inquiry. Moreover, they compare their existing misconceptions with the correct scientific concepts..
In this study, for the Structuring and Negotiating stage of the CKCM, online simulation experiments on alpha and beta decays, as well as fission events, were implemented to students using the website http://phet.colorado.edu/tr/ .
To make students aware of their misconceptions, the worksheets distributed previously included sections suitable for the PEOE (Prediction-Explanation-Observation-Explanation) strategy. In these sections, students were asked to make predictions before starting the simulation experiments and then explain their predictions. After conducting the experiments, they were required to write down their observations and provide explanations.

Alpha Decay Simulation
In the alpha decay simulation, students were given the opportunity to conduct alpha radiation on polonium (Po) element to obtain lead (Pb). Alpha decay simulation on website of (http://phet.colorado.edu/tr/) shown at Figure 2.

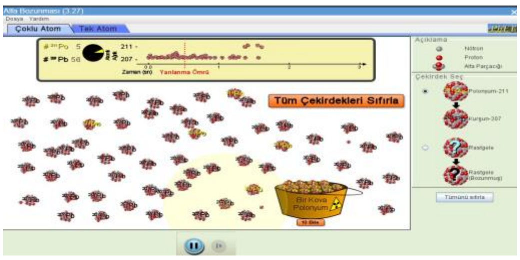

Fig.2. Alpha Decay Simulation

After conducting the simulation experiment, students were asked to fill out the relevant section in their worksheets.

Beta Decay Simulation
In the beta decay simulation, students observed the transformation of hydrogen into helium through beta radiation (Figure 3).

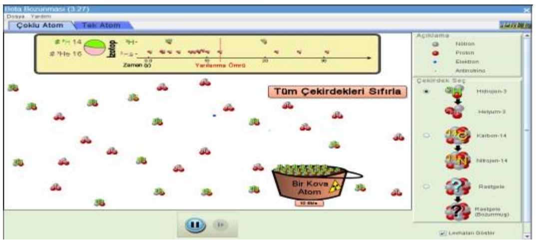

Fig.3. Beta Decay Simulation

Nuclear Fission Simulation

Before conducting the fission reaction simulation experiment, students were asked to answer the section related to the fission experiment in their worksheets using the think-pair-share strategy. Subsequently, they were instructed to fragment a Uranium atom by bombarding it with neutrons using the simulation. After conducting the simulation, students filled out the observation and explanation section in their worksheets. The visual representation of the experiment is shown in Figure 4.

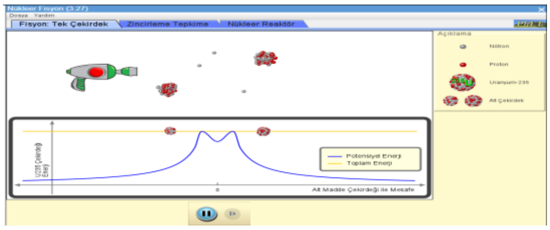

Fig.4. Nuclear Fission Simulation

Activities for Expansion and Transfer Stage

During the Expansion and Transfer stage, students transfer the newly acquired knowledge to socio-scientific issues and the nature of science by considering the context of science, technology, society, and the environment (Ebenezer et al., 2010). This stage emphasizes the Science-Technology-Society-Environment (STSE) interactions (Demircioğlu & Vural, 2016). In Figure 5 shown the sample section item about socio-scientific issues, nuclear power plants positive and negative aspects.

12) Fisyon reaksiyonlarına örnek nükleer enerji santrallerinin olumlu ve olumsuz yönlerini karşılaştırınız.

Nükleer enerji santrallerinin olumlu yönleri.	
Nükleer enerji santrallerinin olumsuz yönleri.	

Fig. 5. Sample section item at worksheet about socio-scientific issues, nuclear power plants positive and negative aspects.

In this study, for the Expansion and Transfer stage, students were provided with worksheets where they were expected to interpret the concepts related to radioactivity socio-scientifically and engage in discussions with their peers. Additionally, they were encouraged to relate the concepts of radioactivity to their daily lives.

Activities for Reflection and Assessment Stage

This stage encompasses the reflection and assessment process, which includes scientific research skills, beliefs, behaviors, attitudes, and social skills. In this step, it is essential to prefer complementary measurement and evaluation methods rather than traditional assessment methods (Bakırcı et al., 2014; Bakırcı & Çepni, 2014;Biernacka, 2006; Bakırcı et al., 2017; Ebenezer & Connor, 1998). The fourth stage of CKCM is an integral part of the other stages (Ebenezer et al., 2010).

In the reflection and assessment stage of CKCM, alternative assessment methods were used to determine students' level of learning on the topic. Students were asked to match the contents in the evaluation activities prepared by adding content to the site wordwall.com, which has ready-made templates. The evaluation activities shown in Figure7 and Figure 8.

In first activity (Figure 7), students were asked to complete the missing words from the given sentences, while in the other evaluation activity; they were asked to associate the given concepts with visuals (Figure 8). At the and of the activities results the results are displayed on the teacher's profile on the site. Results shown in Figure 9 and Figure 10

Fig.7. "Let's fill in the blanks with appropriate words" evaluation activity

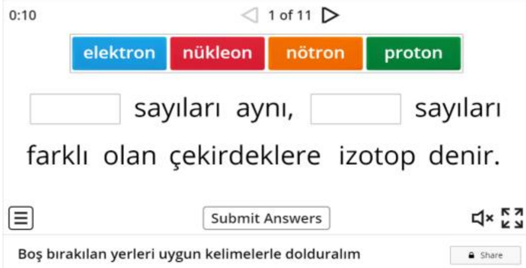

Fig.8. "Let's match" evaluation activity

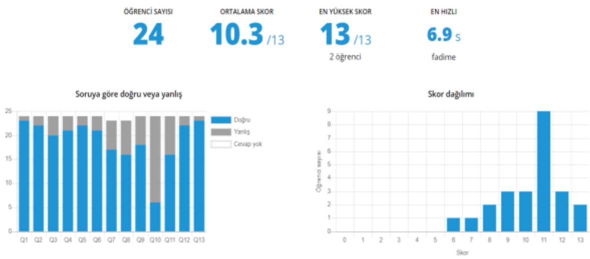

Fig.9. Results of the evaluation activity "Let's fill in the blanks with appropriate words".

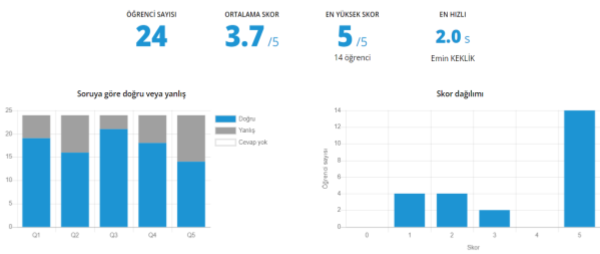

Fig.10. Results of the evaluation activity "Let's match"

4. Findings

In this section, the findings related to the analysis of the RCT applied to the students are presented.

In this stage, the findings regarding the sub-problem "Is there a significant difference in conceptual understanding between the experimental group, where nuclear physics topic is taught using CKCM, and the control group, where it is taught using traditional straight narration method?" were examined. Therefore;

- The normality test applied.

• The pre-test and post-test score averages of the experimental and control groups were compared.
• SPSS 26 software was used to apply independent samples t-test to compare the pre-test and post-test scores of the experimental and control groups.

After applying the nuclear physics concept test, pretest and posttest to the experimental and control groups, it was examined whether the research sample was normally distributed or not. In this examined;

- Skewness and Kurtosis values
- Shapiro-Wilk normality test results given in Table 4.

Table 5:
Research datas skewness-kurtosis values.

	Pre-test	**Post-test**
Skewness	.821	-.058
Std. Skewness Error	.343	.343
Kurtosis	.267	-.985
Std. Kurtosis Error	.674	.674

In order to determine whether the test data showed a normal distribution, the values obtained by dividing the Skewness and Kurtosis skewness and kurtosis values by the skewness and kurtosis error values, respectively, were examined and it was determined that these values were between -1.96 and +1.96. According to these values, it is seen that the data shows a normal distribution (Can, 2014).

Table 6:
Table of Shapiro-Wilk test of normality.

Groups		Shapiro-Wilk		
		Statistic	df	Sig.
Pre	E.G.	,959	24	,423
	C.G	,927	24	**,084**
Post	E.G.	,927	24	**,084**
	C.G	,961	24	,456

E.G: Experimental Group
C.G: Control Group

The Shapiro–Wilk test is more suitable for small sample sizes (<50 samples), but can also be applied to larger samples. The null hypothesis for the Shapiro-Wilk test states that the data are taken from a normally distributed population. If the significance value of the data is $P > 0.05$, the null hypothesis is accepted and the data is called normally distributed (Mishra et al., 2019). When the Shapiro-Wilk Normality Test results are examined (Table 5); Since the significance values are $p>0.05$, the data show normal distribution.

The findings of the independent samples t-test for both groups' pre-test and post-test scores are shown in Table 7.

Table 7.
Radioactivity Concept Test data independent sample t-test findings

	Groups	N	Mean	SS	Levene test F	Levene test p	t	Sd.	p	Cohen d
Pre Test	Experimental group	24	27.13	4.47	7.06	.011	1.275	38.43	0.210*	
	Control Group	24	29.33	7.21						
Post Test	Experimental group	24	46.83	9.52	0.95	.333	2.113	46	0.040**	0.61
	Control Group	24	40.42	11.43						

*p>.05 **p<.05

As a result of the analysis, Considering the post-test scores, it can be concluded that there is a significant difference between the experimental group and the control group in favor of the experimental group in terms of conceptual understanding of radioactivity [t=2,113, **p<.05].
When the lines given in the post-test are examined, it is seen that the correct answers of the students in the 1st and 2nd stages are close to each other. In addition, it is found that students have more correct answers in the posttest.
The Cohen's d value indicates the effect size of CKCM's conceptual understanding of radioactivity. The d value obtained as a result of the calculations is interpreted as follows: .20- small effect size;
.50- medium; .80 is a large effect size (Cohen, 1988). Results of this research is Cohen d= 0,61. It can be concluded that the effect size of OBYM on conceptual understanding of radioactivity is at an acceptable level.

Table 8.
Frequencies of correct answers given to the 1st and 2nd stages in the pre-test

Question number	Experimental group		Control Group	
	1 stage (f)	*Stage 2 (f)*	*1 stage (f)*	*Stage 2 (f)*
1	9	12	10	13
2	12	13	11	13
3	21	22	23	23
4	4	2	5	2
5	5	2	6	2
6	18	10	21	8
7	21	8	18	11
8	17	10	9	8
9	11	3	13	7
10	21	12	19	16
11	9	2	9	7
12	21	14	25	15
13	3	3	9	7
14	9	3	15	11
15	11	10	11	10
16	19	18	19	19
17	5	3	7	5
18	7	5	10	7
19	6	5	4	4
20	7	4	7	5
21	11	10	9	9
22	4	4	5	3
23	9	7	8	4

The frequencies of correct answers given to the 1st and 2nd stages in the pretest and posttest are shown in Table 8 and Table 9.

Examining the pre-test data in Table 4, the students in the experimental and control groups mostly gave correct answers in the first stage of the questions in which the correctness of the judgments given in the questions was asked. It is seen that they gave wrong answers in the second stage, when they were asked to explain their judgments. From here, it can be interpreted that the students do not have enough knowledge to explain the concepts in the subject.

Table 9:
Frequencies of correct answers given to stages 1 and 2 in the posttest

Question number	Experimental group		Control Group	
	1 stage (f)	*Stage 2 (f)*	*1 stage (f)*	*Stage 2 (f)*
1	3	19	8	17
2	18	15	17	14
3	23	23	21	20
4	20	18	14	16
5	18	16	18	8
6	20	8	22	14
7	22	21	23	16
8	23	22	12	12
9	18	17	12	16
10	17	18	15	19
11	12	13	14	11
12	23	16	23	14
13	14	12	13	11
14	21	19	19	18
15	11	8	16	17
16	16	17	14	14
17	15	15	12	9
18	21	21	15	10
19	17	15	12	8
20	22	19	17	15
21	16	17	9	9
22	18	15	12	12
23	21	20	17	18

When the post-test data are examined, it is seen that the correct answer numbers of the students in the 1st and 2nd stages are close to each other. When the answers of the experimental and control groups are analyzed separately, it can be concluded that the students in the experimental group had more correct answers in the 1st and 2nd stages than the control group. However, in the 1st question, both groups of students gave wrong answers to the 1st stage in the pre-test and post-tests, and gave the correct answer to the 2nd stage.

The number of correct answers given by both groups in the posttest increased. This increase rate was higher in the experimental group than in the control group. The questions with the highest increase in correct answers; In the 4th question about the concept of "nuclear stability", the 5th question about the "radioactivity", the 14th question about the "harms of radiation" and the 18th, 19th and 20th questions about the "radiation types".

The percentages of correct answers given by the experimental and control groups in the pretest and posttest were calculated. The calculated percentages are given in Figure 11, Figure 12, Table 8 and Table 9.

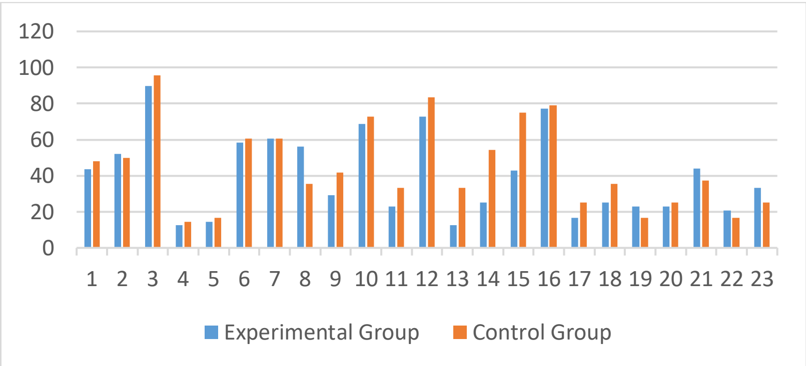

Fig. 11. Correct answer percentages of the groups in the pretest for the Radioactivity Concept Test.

When the graph given in Figure 11 is examined, it can be concluded that the percentages of correct answers given by the experimental and control groups in the pre-test are close to each other. In addition, it is seen that the correct answer rates of the students are quite low. It is observed that some control group students answered 13th, 14th, 15th questions more correctly than the experimental group. This can be explained by the fact that these questions in the test are more open to interpretation.
The percentages of correct answers given by the experimental and control groups in the posttest are shown in Figure 12.

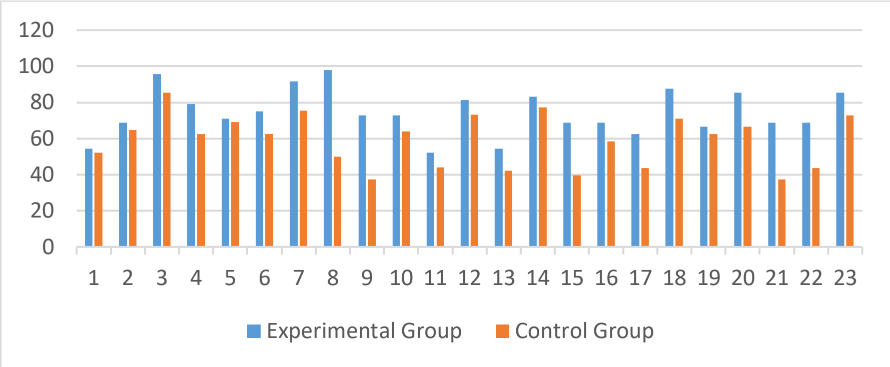

Fig. 12. Correct answer percentages of the groups in the posttest for the Nuclear Physics Concept Test.

When the graph in Figure 12 is examined, it is observed that the correct answer rates of both groups have increased. The percentage of correct answers of the experimental group students was higher than the control group.
The percentages of correct answers given by the experimental and control group students in the pre-test and post-test are given in Table 10.

Table 10.
Frequency and percentage of correct answers given by experimental and control group students to pre-test and post-test

	Pre Test				Post Test			
	Exp. group		Control Group		Exp. group		Control Group	
Question	(f)	%	(f)	%	(f)	%	(f)	%
1	21	43,7	23	47,9	26	54,2	25	52,1
2	25	52,1	24	50	33	68,7	31	64,6
3	43	89,6	46	95,8	46	95,8	41	85,4
4	6	12,5	7	14,6	38	79,2	30	62,5
5	7	14,6	8	16,7	34	7,8	36	75
6	28	58,3	29	6,4	36	75	30	62,5
7	29	6,4	29	6,4	44	91,7	39	81,3
8	27	56,3	17	35,4	47	97,9	24	50
9	14	29,2	20	41,7	35	72,9	18	37,5
10	33	68,8	35	72,9	35	72,9	34	7,8
11	11	22,9	16	33,3	25	52,1	23	47,9
12	35	72,9	40	83,3	39	81,3	37	77,1
13	6	12,5	16	33,3	26	54,2	24	50
14	12	25	26	54,2	40	83,3	37	77,1
15	21	43,	21	75	33	68,6	19	39,6
16	37	77,1	38	79,2	33	68,6	28	58,3
17	8	16,7	12	25	30	62,5	21	43,6
18	12	25	17	35,4	42	87,5	34	7,8
19	11	22,9	8	16,7	32	66,7	30	62,5
20	11	22,9	12	25	41	85,4	32	66,7
21	21	43,8	18	37,5	33	68,8	18	37,5
22	10	2,8	8	16,7	33	68,8	21	43,8
23	16	33,3	12	25	41	85,4	35	72,9

This difference is greatest in questions 8 and 9, where core stability is asked. In the 5th question in which the concept of "radioactivity" was asked, the correct answer rate of both groups was very close to each other.

5. Discussion and Suggestions

In this research, "Is there a significant difference in terms of conceptual understanding between the experimental group in which the subject of radioactivity is taught with CKCM and the control group in which the traditional lecture method is taught?" question has been explored. It can be said that when applying CKCM, it goes through different stages from traditional education. During the exploration and categorization stage, the students gained prior knowledge and learned the opinions of other students. Thus, they were aware of the information they had and had the opportunity to compare them with different views. In this regard, Hewson and Hewson emphasized that teachers should determine their previous knowledge and alternative concepts before starting teaching. In addition, the learning environment needs to be prepared accordingly (Hewson & Hewson, 1988). In addition, an infrastructure has been created to concretize abstract concepts with posters and videos.

In the research, the effect of the instruction prepared in accordance with CKCM on the conceptual meanings of science education students about radioactivity was questioned. In the results of the Nuclear Physics Concept Test applied to the students, it is seen that there is no significant difference between the two groups in the pre-test scores applied before teaching the experimental and control groups.

When the post-test scores were examined, it was concluded that there was a significant difference between the groups in favor of the experimental group. Based on these results; It can be interpreted that the Common Knowledge Construction Model is more effective than the traditional lecture method on the conceptual understanding of pre-service science teachers about radioactivity. This result similar with other research in literature (Bakırcı et al.,2016; Ebenezer et al., 2010; Ertuğrul, 2015; Kiryak, 2013) research result. There can be several reason of this result. In CKCM students can experiences active learning and it can affect the conceptual understand. Uzunkaya (2019) also concluded in their study that CKCM was more effective on students' conceptual understanding compared to the 5E model. As a result of the study conducted by Akgün et al., (2016) it was concluded that CKCM increased the academic success of students and developed positive attitudes towards science lessons, while the active learning process of students was positively affected. Another example is in his study, Wood (2012) examined the effect of CKCM on the academic achievement of high school students in acid-base subjects. The sample was divided into two groups: experimental and control groups. While CKCM was applied to the experimental group, the direct explanation method was applied to the control group. As a result of the study, the researcher determined that CKCM was more effective than plain lecture on the acid-base topic and also concluded that it had a positive impact on the academic success of students.

The misconceptions that the students had in the pre-test decreased in both groups in the post-test. It is one of the results of this study that traditional teaching is also effective in eliminating students' misconceptions. When the reasons for this result are examined, students' lack of knowledge is counted among the causes of misconceptions. (Coştu et al., 2007). For this reason, according to the results obtained from the research, it can be said that the students made sense of the concepts of radioactivity, which they frequently encounter in daily life and do not have detailed information about.

It was concluded that the experimental group students' conceptual understanding increased more than the control group. Among the reasons for this, it can be said that the fact that there are different stages in the implementation of CKCM from traditional teaching has a positive contribution. During the exploration and categorization stage, the students had the chance to compare with other opinions, since the students' prior knowledge was taken and they were aware of the opinions of their peers. Hewson and Hewson (1988) also emphasized that the teacher's prior knowledge and alternative concepts should be discovered before they start teaching and the learning environment should be prepared accordingly. In addition, an infrastructure has been created to concretize abstract concepts with posters and videos.

The PEOE strategy was included in the worksheets distributed to the students during the "structuring and negotiation" stage, which is the second stage of CKCM. Students were asked to write down the knowledge they had about the given concepts. Then, they were provided with accurate information through lectures, videos and experiment simulations. Finally, they were asked to compare their preliminary information with the correct information. Thus, it was ensured that the students realized their alternative concepts and misconceptions by writing them down. It can be said that this method is

effective in students' conceptual understanding. Karataş et al. (2003) stated that the PEOE strategy enables students to question the nature of phenomena and enables students to support their knowledge and experience with predictions. In the studies in the literature, it has been concluded that the PEOE method helps to improve the conceptual understanding of the students (Bakırcı, 2014; Benli Özdemir, 2014; Coştu & Haydari, 2012; Kiryak, 2013; Köseoğlu, et al., 2002).
When the correct answer results of the experimental group students are examined, the questions with the highest increase in correct answers are the fourth question about the concept of "core stability", the fifth question about the "radioactivity", the fourteenth question about the "harms of radiation", the eighteenth, nineteenth and twentieth questions about "radiation types". While teaching with CKCM, videos and experiment simulations were used while explaining the subjects of "nuclear stability", "radioactivity", "radiation types". Considering this result, it can be said that video and experiment simulations contribute positively to students' conceptual understanding. Sakman (2020) stated that simulators and animations accelerate students' learning and contribute to the permanence of knowledge.

CKCM can also be used in teaching other science subjects in science lessons due to its positive effect on students' course achievement. Because of its positive effect in eliminating students' misconceptions, the CKCM can be used in teaching science subjects such as radioactivity where there are many misconceptions. A large time interval is needed when using the CKCM. For this reason, the hours of classes in which CKCM will be used can be increased and finally, this study was carried out with distance education due to the pandemic. More experiments and activities can be done when using CKCM in face-to-face teaching.

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