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# The Impact of the 5E Learning Model Improved with Concept Maps on Motivation

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The examination of students' motivation towards lessons is an important aspect of educational studies. The constructivist approach significantly impacts the improvement of students' motivation. The present study aims to examine the use of the 5E learning model with concept maps to support students' motivation and compare the 5E approach and the classical approach to teaching chemistry in terms of motivational dimensions. The main subject of this study is an assessment of students' motivation using the 5E learning model, which promotes student-centred teaching. The study was conducted with 100 8th-grade lower secondary school students who attended a school in the Turkish Republic of Northern Cyprus (TRNC) during the spring semester of the 2018/19 school year. The study was conducted with two randomly selected groups: experimental (EG) and control (CG). The lessons of the EG were taught using the 5E Learning Model Improved with Concept Maps, while lessons of the CG were conducted using the current, conventional teaching method. The Motivated Strategies for Learning Questionnaire (MSLQ) was applied as a data collection tool in the study. Descriptive statistics and Multivariate Analysis of Variance (MANOVA) were used in data analysis. As a result, it was determined that the EG students' motivation scores showed a significant difference from the CG students' motivation scores. Furthermore, a significant difference was established between the EG and CG students' intrinsic goal orientation and test anxiety post-test scores. Although the EG students' averages for other sub-dimensions were higher than the CG students' averages, no significant difference was found between the groups.

**Keywords:** concept maps, motivation, lower secondary school students, 5E learning model

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# Vpliv učnega modela 5 E, izboljšanega s konceptualnimi modeli, na motivacijo

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Preučevanje motivacije učencev za pouk je pomemben vidik pedagoških študij. Konstruktivistični pristop pomembno vpliva na izboljšanje motivacije pri učencih. Namen te študije je preučiti uporabo učnega modela 5 E s konceptualnimi modeli za podporo motivacije pri učencih ter primerjati pristop 5 E in klasični pristop k poučevanju kemije z vidika motivacijskih razsežnosti. Glavni predmet te študije je ocena motivacije pri učencih z uporabo učnega modela 5 E, ki spodbuja poučevanje, osredinjeno na učence. Študija je bila izvedena s 100 učenci zadnjega triletja osnovne šole (8. in 9. razreda), ki so obiskovali šolo v turški republiki Severni Ciper v spomladanskem semestru šolskega leta 2018/19. Študija je bila izvedena z dvema naključno izbranima skupinama: eksperimentalno (ES) in kontrolno (KS). Pouk ES je potekal po učnem modelu 5 E, izboljšanem s konceptualnimi modeli, pouk KS pa po zdajšnji, tj. običajni metodi poučevanja. Kot orodje za zbiranje podatkov je bil v študiji uporabljen vprašalnik motivacijskih prepričanj in učnih strategij (MSLQ). Pri analizi podatkov sta bili uporabljeni opisna statistika in multivariatna analiza variance (MANOVA). Na podlagi analize je bilo ugotovljeno, da se rezultati motivacije učencev ES pomembno razlikujejo od rezultatov motivacije učencev KS. Poleg tega je bila ugotovljena pomembna razlika med rezultatom notranje ciljne usmerjenosti in testne anksioznosti učencev ES in KS po opravljenem testu. Čeprav so bila povprečja učencev ES za druge poddimenzije višja od povprečij učencev KS, med skupinama ni bila ugotovljena pomembna razlika.

**Ključne besede:** konceptualni modeli, motivacija, učenci zadnjega triletja osnovne šole, učni model 5 E

## Introduction

Motivation is one of the main factors influencing whether students are willing to learn about a subject or solve a problem (Akbaba, 2006). Motivation affects an individual's performance (Kian et al., 2014). Motivation is a complex process in which purposive action is initiated and continued (Schunk et al., 2008; Sharaabi-Naor et al., 2014). Akbaba (2006) states that motivation is one of the sources that determine student behaviours at school and, accordingly, affects the speed of reaching goals in educational environments.

The literature suggests that various teaching methods, models, and strategies employed in chemistry lessons can enhance student motivation (Demircioğlu et al., 2019; Kutu & Sözbilir, 2011; Tosun & Taşkesenligil, 2012). Demircioğlu et al. (2019) reported that teaching based on the REACT strategy (which has five steps: relating, experiencing, applying, cooperating, and transferring), which is based on a context-based learning approach, positively affects the motivation of 10$^{th}$-grade students regarding chemistry lessons.

Many studies have investigated the motivation of students at various educational levels, including secondary school and university, towards chemistry courses (Austin et al., 2018; Cetin-Dindar & Geban, 2015; Gunes et al., 2020; Şen & Yılmaz, 2014; Tosun, 2013). Tosun et al. (2013) noted that the Problem-Based Learning (PBL) approach was found to increase the motivation of undergraduate students in chemistry lessons. Similarly, Korkut and Oren (2018) found that the use of science stories supported by concept cartoons increased 7$^{th}$-grade students' motivation. Moreover, the motivation of secondary school students has been discussed in various studies conducted on other branches of science education, such as physics and biology (Aydin, 2016; Snetinová et al., 2018).

Concept maps are graphical tools used to organise and reflect information. They consist of boxes representing concepts and lines connecting these concepts to illustrate their relationships (Novak, 1990). Studies on chemistry education have highlighted the use of concept maps in classrooms (Aguiar & Correia, 2016; Singh & Moono, 2015; Talbert et al., 2020). Kilic and Cakmak (2013) stated that concept maps were one of the most effective tools to support meaningful learning. Additionally, concept maps have been used as evaluation tools to identify misconceptions and as teaching materials in science education studies (Austin & Shore, 1995; Bulut et al., 2021; Ries et al., 2022; Sari & Bayram, 2018). According to the studies in the literature, the concept maps have positive effects on students' academic achievement, motivation, logical thinking, and problem-solving skills (Abd El-Hay et al., 2018; Bektuzun & Yel; 2019; Kara & Kefeli, 2018; Ozgun & Yalcin, 2019). Moreover, studies revealed that the use of concept maps with various strategies, methods, and techniques increases students' motivation throughout the course (Chen et al., 2016; Kostova & Radoynovska, 2010; Keraro et al., 2007).

Atkin and Karplus (1962) introduced the learning cycle model with three phases (i.e., exploration, invention, and discovery). In contrast, the 5E learning model proposed by Bybee et al. (2006) comprises five steps: 1) engagement, 2) exploration, 3) explanation, 4) elaboration, and 5) evaluation. The 5E learning model, based on the constructivist approach, enables students to use their knowledge and skills actively and improves students' motivation (Pirci & Torun, 2020). Furthermore, several studies in the literature stated that the 5E learning model enhanced learning motivation in science classes (Guven et al., 2022; Putra et al., 2018; Rizki et al., 2023). Studies have also demonstrated that the 5E learning model, as an application of constructivist learning theory, positively affects students' motivation, attitude, and success (Demir & Emre, 2020; Putra et al., 2018; Yalcin Altun et al., 2010). In this context, recent studies have also explored the use of the 5E learning model in conjunction with different techniques, methods, and strategies (Bagci & Yalin, 2018; Koc & Sarikaya, 2020; Utami & Subali, 2020). Additionally, the incorporation of concept maps has been shown to contribute positively to students' achievement, attitude, logical thinking, and motivation (Akgunduz & Bal, 2013; Chawla & Singh, 2015; Chiou, 2015; Çömek et al., 2016; Kara & Kefeli, 2018).

This study builds on these findings to investigate the utilisation of the 5E learning model with concept maps to support students' motivation and compare the 5E approach with the classical approach to teaching chemistry in terms of motivational dimensions.

Pintrich et al. (1991) developed the Motivated Strategies for Learning Questionnaire (MSLQ) to assess students' motivation with six sub-dimension: 1) intrinsic goal orientation, 2) extrinsic goal orientation, 3) task value, 4) control of learning beliefs, 5) self-efficacy for learning and performance, and 6) test anxiety. Effective self-regulative learning characteristics, such as intrinsic goal orientation and self-efficacy, positively affect success (Chyung et al., 2010). Intrinsic motivation provides satisfaction derived from the task itself, whereas extrinsic motivation is driven by external factors, such as rewards or punishments based on task performance (Lin et al., 2003). The task value relates to the beliefs about the importance of the task (Pintrich, 1999). The control of beliefs reflects students' ideas regarding their level of control over their own learning (Pintrich & Garcia, 1993). Test anxiety encompasses worry and emotional distress related to exams and negatively affects the students (Pintrich & Garcia, 1993). Therefore, when examining motivation in the context of chemistry education, it is important to consider components such as task value, self-efficacy, and test anxiety, as they have been studied extensively (Karpudewan et al., 2015; Lynch & Trujillo, 2011; Zusho et al., 2003).

Güngör Seyhan (2020) found that high school students' motivation in chemistry lessons predicted their attitudes towards the subject, as well as their self-efficacy and self-regulatory learning strategies. Studies consistently show a significant relationship between students' motivation, achievement, and performance in chemistry courses (Eskicioglu & Alpat, 2017; Ferrell et al., 2016). Accordingly, Zusho et al. (2003) emphasised that self-efficacy and task value, as the components of motivation, were the best predictors of students' success in chemistry courses. Concordantly, in studies on mathematics and science education, a positive and significant relationship between students' motivation and their achievement, attitude, metacognitive awareness, and scientific creativity levels has been observed (Atay, 2014; Azizoğlu & Çetin, 2009; Çeliker et al., 2015; Yıldırım & Kansız, 2018). Moreover, the meta-analysis study conducted by Alkan and Bayri (2017) revealed a statistically significant and positive relationship between motivation and achievement towards science. Thus, it is crucial to investigate the impact of the 5E Learning Model Improved with Concept Maps on motivation within the context of the chemistry courses.

This study aims to examine the influence of the 5E Learning Model Improved with Concept Maps on the motivation of secondary school students. In accordance with this purpose, we aimed to investigate the use of the 5E learning model with concept maps that support students' motivation and to compare the 5E approach with the classical approach to teaching chemistry in terms of motivational dimensions. The findings from this study will provide important evidence regarding the effect of learning environments on students' motivation. In line with this purpose of the study, the answer to the following question was investigated.

1. 'Is there a significant difference between experimental (EG) and control groups (CG) students' motivation (intrinsic goal orientation (IGO1), extrinsic goal orientation (EGO2), task value (TV3), control of learning beliefs (CLB4), self-efficacy for learning and performance (SELP5), test anxiety (TA6)) according to the teaching method?'

## Method

This section describes the study participants, data collection tool, research design, the application process, the implementation of concept maps to steps of the 5E learning model and the data analysis employed.

### Participants

The purposive sampling method was used for sample selection. In this direction, a secondary school that admitted students through an examination and provided a similar educational background was selected. The research was carried out with 100 students in the 8$^{th}$ grade and aged 13 and 14 during the second semester of the 2018/19 academic year. The study was performed with two experimental groups (EG (female: 22, male: 28)) and two control groups (CG (female: 21, male: 29)), which were selected randomly. All participants voluntarily took part in the research.

The study was approved by the Ethical Committee of Hacettepe University. Additionally, the presented study was verified by the TRNC National Education Ministry.

### Instrument

The Motivated Strategies for Learning Questionnaire (MSLQ) was used as the data collection tool for the study.

Motivated Strategies for Learning Questionnaire (MSLQ): The MSLQ is an assessment tool developed by Pintrich et al. (1991) to investigate students' motivational orientation and use of various learning strategies. The questionnaire was adapted to Turkish by different researchers (Altun & Erden, 2006; Büyüköztürk et al., 2004; Karadeniz et al., 2008; Sungur, 2004). The seven-point Likert scale comprises two basic components as motivation and learning strategies. The sub-dimensions of the scale are modular that can be used individually or together in accordance with the purpose of the study (Büyüköztürk et al., 2004). The motivation dimension of the scale consists of 31 items that evaluate students' beliefs about the purpose and value, beliefs about their ability to succeed and concerns about the tests within the course (Pintrich et al., 1991). For the evaluation of the scale, it is stated that the score obtained by the student from each factor indicates the characteristic of the relevant factor at such a high or low level (Büyüköztürk et al., 2004; Pintrich et al., 1991). In this study, the motivation dimension utilised the IGO1, EGO2, TA3, TV4, CLB5, and SELP6 sub-dimensions. The scale was adapted for the chemistry course by Şen (2015). The scale adapted by Şen (2015) was used in the study. For validity and reliability analysis, the scale was administered to 334 secondary school students. Confirmatory Factor Analysis was performed to examine the scale's construct validity, and Cronbach's alpha internal consistency coefficients were calculated for each sub-dimension to determine reliability. Karadeniz et al. (2008) reported that the corrected total item correlation values for the motivation dimension of the scale include 6 factors, ranging between *.15* and .58. Table 1 presents the Cronbach's alpha coefficients calculated within the context of this study regarding the motivation dimension of the scale, along with the values calculated for the original scale (Pintrich et al., 1991), and the adapted scale (Büyüköztürk et al., 2004).

**Table 1**
*Cronbach's Alpha Coefficients for Motivation Dimension*

| Sub-dimension | Current Scale | Original Scale | Adapted Scale |
|---|---|---|---|
| IGO1 | .61 | .74 | .59 |
| EGO2 | .75 | .62 | .63 |
| TV3 | .88 | .90 | .80 |
| CLB4 | .65 | .68 | .52 |
| SELP5 | .93 | .93 | .86 |
| TA6 | .66 | .80 | .69 |

O'Rourke et al. (2005) stated that Cronbach's Alpha values below 0.70 may be sufficient and that social scientists sometimes report values below 0.60. Therefore, it was decided that Cronbach's Alpha values were sufficient for reliability.

In this study, "fit statistics were calculated for the six factors specified in the motivation dimension. As a consequence of the analysis, it was found that the fit indices (*NNFI = .95, NFI = .92, CFI = .96, RMSEA = .075*), especially *chi-square/df = (947/422) = 2.24*" (Varoglu, 2021; pp. 44). Garver and Mentzer (1999) suggested using NNFI, CFI and RMSEA values to determine model-data fit. Considering the results of the analysis, it is revealed that the RMSEA value is less than .08, the CFI value is greater than .90, the NFI and NNFI values are also greater than .90., and the model is fitted with the data (Schermelleh-Engel et al., 2003).

## Research design

This present study examined the impact of the 5E Learning Model Improved with Concept Maps on motivation among 8$^{th}$-grade students. In this context, the study was performed with two experimental (EG) and two control groups (CG) with a non-equivalent control group design, a quantitative research method. The EG consisted of 50 students, with 26 students in one group and 24 in the other. Similarly, the CG comprised 50 students, with 25 students in each group.

## Application process

This study aimed to examine the impact of the 5E Learning Model Improved with Concept Maps on the motivation of 8$^{th}$-grade students within the context of the periodic table, which is an essential topic in a chemistry course. In the study, we worked with two experimental and two control groups. In the teaching method applied to the experimental group, concept maps were systematically used in the exploration (2$^{nd}$ step), explanation (3$^{rd}$ step) and evaluation (5$^{th}$ step) steps of the 5E model; therefore, the 5E Learning Model was improved. Simultaneously, the control group received lessons with the existing teaching method. MSLQ was applied as a pre-test to both EG and CG students in the first week of the application. Then, the EG students were provided information about the concept maps to ensure they could prepare them. Considering that each student would have an idea about 'water', the concept map application was made and ensured that the students could easily create concept maps and establish crosslinks. In contrast, none of the constructivist activity was done with CG, which only received information about water. The lessons of the EG students were conducted with the 5E Learning Model Improved with Concept Maps, while CG students continued with the current teaching method, which did not include constructivist activities. The current teaching model for CG followed a conventional teacher-centred approach in which the teacher used a textbook with direct instruction methods. The same subjects were taught with EG. In this context, the formation of ions is based on the concepts of anion and cation and chemical bonding in relation to the subject of the periodic table presented by the teacher. The study was completed by applying the MSLQ as a post-test to both the EG and CG students.

## Implementation of concept maps to 2nd, 3rd, and 5th steps of 5e learning model

This section explains the activities prepared regarding the periodic table by the 5E Learning Model Improved with Concept Maps with examples. First, we state that the students were informed about the 5E Learning Model and concept maps prior to the application. Doing so ensured that the students were ready to use the concept maps by making applications related to them.

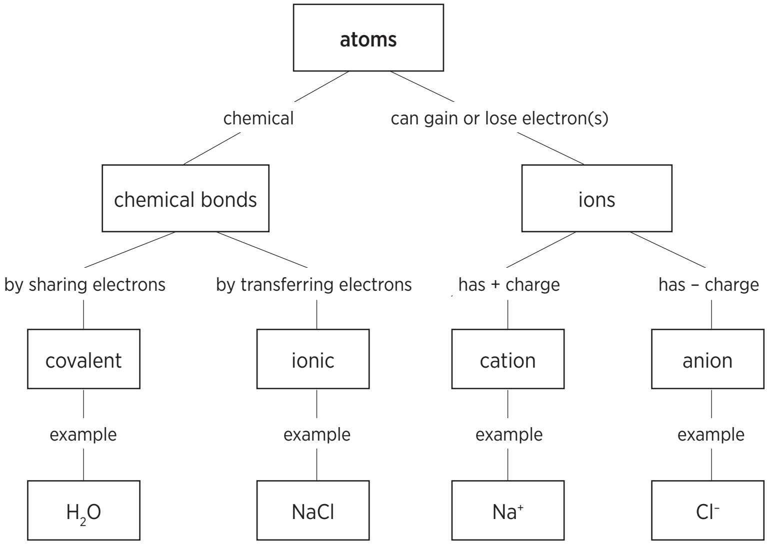
**Engagement Step:** To engage the attention of the students to the periodic table, an activity of preparing identity cards for the elements was carried out. The students were prompted with the question, 'What kind of information should be included if an identity card were to be prepared for an element?'. This activity aimed to shift the students' focus towards the elements in the periodic table and encourage them to think about the essential information related to each element that should be included on the identity cards.

**Exploration Step:** In this step, students were encouraged to work together while the teacher took on a passive role. The students were divided into two groups (with 13 students in each group in EG1 and 12 students in each group in EG2) to support working together. The groups were provided with fill-in-the-blank type questions related to the periodic table. These questions required the students to make comments by using the periodic table. For example, it asked the groups to indicate the elements arranged by their atomic number using the periodic table. The students were asked to write down these answers, which were the concepts involved in the periodic table. In favour of these fill-in-the-blank-type questions, the students noted down the concepts related to the periodic table, such as group, period, atomic number, and metal or non-metal. Next, the students create a concept map by establishing a relationship between these concepts.

**Explanation Step:** In this step, the teacher took an active role and used a concept map to provide explanations. Figure 1 shows a concept map prepared and used by the teacher.

**Figure 1**

*An example of a concept map is prepared for the explanation step (Varoglu, 2021).*




**Elaboration Step:** An activity is prepared so that what the students have learned is taken one step further and applied. The students were divided into groups of three or four, and a team tournament was held. The students answered the questions by using the periodic table, which was on the board. In this way, students were asked to apply and interpret what they had learned on the periodic table for other elements. For example, the groups were asked to classify the element boron as a metal, non-metal, or semi-metal, write two metals and two non-metals in the second period, and indicate whether hydrogen is a metal or a non-metal.

**Evaluation Step:** Concept maps were used to evaluate students' learning in this step. In this context, the students created a concept map from scratch related to the concepts they had learned. Additionally, to support this step, a puzzle and a structured grid were prepared about the concepts applied.

The application began with the used of the pre-tests and was completed in about one month with the use of the post-tests, focusing on the topic of the periodic table. Throughout this period, it was thought that the teaching model applied to the experimental group, which is an application of the constructivist approach, would affect the students' motivation components towards the chemistry lesson.

## Data analysis

The quantitative data acquired from the study were analysed with statistical analysis by using the IBM SPSS Statistics 20 software. The descriptive statistics (mean, standard deviation, minimum, maximum, skewness and kurtosis) were examined. Inferential statistics were used after the necessary assumptions were provided. Multivariate Analysis of Variance (MANOVA) analysis was used to determine the scores of students that acquired the Motivational Strategies for Learning Questionnaire (MSLQ).

## Results

Table 2 shows the descriptive statistics of the pre-test scores for motivation sub-dimensions of both the EG and CG students. The fact that the kurtosis and skewness values of the students' pre-test scores are between +2 and -2 indicates that the scores comply with the normal distribution (George & Mallery, 2003). Table 2 revealed that the scores of the students in the EG and CG were close to each other. Before the analysis, the assumptions of the MANOVA analysis were verified as having been met.

**Table 2**

*Descriptive Statistics for Pre-Test Scores (Mean (M), standard deviation (SD), sample size (N), skewness, kurtosis, minimum and maximum values)*

| Sub-dimension | Group | *Mean* | *df* | *N* | *Skewness* | *Kurtosis* | *Min.* | *Max.* |
|---|---|---|---|---|---|---|---|---|
| IGO1 | EG | 19.48 | 4.32 | 50 | -.717 | -.011 | 8 | 27 |
| | CG | 18.86 | 4.15 | 50 | -.312 | .004 | 8 | 28 |
| | Total | 19.17 | 4.22 | 100 | -.506 | -.129 | 8 | 28 |
| EGO2 | EG | 18.62 | 5.80 | 50 | -.939 | .472 | 4 | 28 |
| | CG | 20.50 | 4.92 | 50 | -.377 | -.312 | 9 | 28 |
| | Total | 19.56 | 5.44 | 100 | -.772 | .506 | 4 | 28 |
| TV3 | EG | 28.76 | 9.16 | 50 | -.696 | -.510 | 10 | 42 |
| | CG | 30.88 | 8.18 | 50 | -1.148 | .953 | 7 | 42 |
| | Total | 29.82 | 8.70 | 100 | -.896 | -.001 | 7 | 42 |
| CLB4 | EG | 21.78 | 4.16 | 50 | -.709 | .204 | 10 | 28 |
| | CG | 20.96 | 4.29 | 50 | -.615 | -.252 | 11 | 28 |
| | Total | 21.37 | 4.22 | 100 | -.649 | -.099 | 10 | 28 |
| SELP5 | EG | 35.74 | 12.71 | 50 | -.595 | .337 | 8 | 54 |
| | CG | 38.52 | 10.04 | 50 | -.741 | .503 | 10 | 55 |
| | Total | 37.13 | 11.48 | 100 | -.717 | .029 | 8 | 55 |
| TA6 | EG | 18.58 | 7.42 | 50 | .329 | -.626 | 6 | 35 |
| | CG | 19.40 | 5.93 | 50 | -.086 | -.838 | 7 | 30 |
| | Total | 18.99 | 6.69 | 100 | .147 | -.657 | 6 | 35 |

Note: EG=experimental group, CG=control group

The findings of the MANOVA analysis performed on the scores for the sub-dimensions indicated in Table 3 reveal that there is a significant difference in the pre-test scores between the EG and CG students $((\Lambda) = .849, F(6, 93) = 2.748, p < .05)$ (Varoglu, 2021; p.81). According to this result, the scores to be obtained from the linear component consisting of the pre-test scores of the students indicate a difference when compared to the experimental and control groups. However, when the sub-dimensions were examined one by one, it was seen that the pre-test results were very close to each other. *The Table of Tests of Between Subjects Effects* shows that the sub-dimensions did not make a significant difference (Varoglu, 2021). Table 3 reflects the results of the analysis.

**Table 3**

*Tests of Between-Subjects Effects for Motivation Pre-Test Scores by Sub-Dimensions*

| Source | Dependent Variable | *Sum of Squares* | *df* | *Mean Square* | *F* | *sig.* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Group | IGO1 | 9.610 | 1 | 9.610 | .536 | .466 | .005 |
| | EGO2 | 88.360 | 1 | 88.360 | 3.053 | .084 | .030 |
| | TV3 | 112.360 | 1 | 112.360 | 1.491 | .225 | .015 |
| | CLB4 | 16.810 | 1 | 16.810 | .942 | .334 | .010 |
| | SELP5 | 193.210 | 1 | 193.210 | 1.472 | .228 | .015 |
| | TA6 | 16.810 | 1 | 16.810 | .373 | .543 | .004 |

The results obtained as an outcome of the descriptive statistics of the post-test scores are given in Table 4. To test the properties of the data for the normal distribution, skewness and kurtosis values were inspected. The fact that the skewness and kurtosis coefficients, which provide information about the symmetry and peak of the distribution, are between +2 and -2 is a sufficient parameter for the normal distribution (George & Mallery, 2003; Perry et al., 2017). Recent studies have pointed out that larger kurtosis and skewness values can be accepted for the normal distribution (Iyer et al., 2017; Orcan, 2020). Kallner (2018) reported that the kurtosis value is an expression of the sharpness of the distribution, and the kurtosis can take up to three values as a normal distribution.

**Table 4**

*Descriptive Statistics for Post-Test Scores (Mean (M), standard deviation (SD), sample size (N), skewness, kurtosis, minimum and maximum values)*

| Sub-dimension | Group | *Mean* | *SD* | *N* | *Skewness* | *Kurtosis* | *Min.* | *Max.* |
|---|---|---|---|---|---|---|---|---|
| IGO1 | EG | 23.20 | 2.92 | 50 | -.421 | -.631 | 17 | 28 |
| | CG | 20.96 | 2.99 | 50 | -.366 | .027 | 14 | 27 |
| | Total | 22.08 | 3.15 | 100 | -.337 | -.288 | 14 | 28 |
| EGO2 | EG | 19.20 | 4.16 | 50 | .052 | -.417 | 9 | 27 |
| | CG | 21.08 | 3.86 | 50 | -.350 | -.740 | 13 | 28 |
| | Total | 20.14 | 4.10 | 100 | -.165 | -.673 | 9 | 28 |
| TV3 | EG | 33.70 | 5.44 | 50 | -.845 | .367 | 20 | 42 |
| | CG | 31.70 | 5.92 | 50 | -1.344 | 2.264 | 12 | 41 |
| | Total | 32.70 | 5.75 | 100 | -1.105 | 1.555 | 12 | 42 |
| CLB4 | EG | 18.60 | 3.81 | 50 | -.499 | -.029 | 9 | 25 |
| | CG | 19.12 | 3.63 | 50 | -.401 | .022 | 9 | 26 |
| | Total | 18.86 | 3.71 | 100 | -.453 | -.037 | 9 | 26 |
| SELP5 | EG | 42.10 | 8.95 | 50 | -.826 | .030 | 21 | 54 |
| | CG | 38.76 | 8.93 | 50 | -.620 | .480 | 15 | 53 |
| | Total | 40.43 | 9.05 | 100 | .241 | .094 | 15 | 54 |
| TA6 | EG | 15.90 | 5.72 | 50 | .450 | -.697 | 7 | 28 |
| | CG | 20.34 | 5.28 | 50 | -.054 | -.402 | 9 | 31 |
| | Total | 18.12 | 5.91 | 100 | .101 | -.797 | 7 | 31 |

Note: EG=experimental group, CG=control group

In the comparison of post-test scores, MANOVA analysis was performed based on the fact that there was no significant difference between the pre-test scores. The results of the MANOVA analysis performed on the scores for the sub-dimensions are given in Table 5. The results of the MANOVA analysis on the scores for the sub-dimensions reveal that there is a significant difference between the post-test scores of the EG and CG students (($\Lambda$) = .700, $F$ (6, 93) = 6.629, $p < .05$) (Varoglu, 2021; pp. 83).

Bonferroni adjustment is required to determine a more reliable significance level to reduce the probability of a Type 1 error rate (Tabachnick et al., 2007). Since the number of dependent variables in the study was 6, the value of .05 was divided by 6, and the value of .0083 was obtained; this value was accepted as the new significance level. Table 5 shows the Analysis of Variance Table.

**Table 5**

*Tests of Between-Subjects Effects for Motivation Post-Test Scores by Sub-Dimensions*

| Source | Dependent Variable | *Sum of Squares* | *df* | *Mean Square* | *F* | *sig.* | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Group | IGO1 | 125.440 | 1 | 125.440 | 14.362 | .000 | .128 |
| | EGO2 | 88.360 | 1 | 88.360 | 5.482 | .021 | .053 |
| | TV3 | 100.000 | 1 | 100.000 | 3.092 | .082 | .031 |
| | CLB4 | 6.760 | 1 | 6.760 | .488 | .486 | .005 |
| | SELP5 | 278.890 | 1 | 278.890 | 3.489 | .065 | .034 |
| | TA6 | 492.840 | 1 | 492.840 | 16.264 | .000 | .142 |

Table 5 shows that the students' intrinsic goal orientation (IGO1) and test anxiety (TA6) post-test scores show a significant difference ($p < .008$) between the EG and CG groups.

As a result, when the pre-test scores of experimental and control group students were examined, it was concluded that there was no significant difference between the scores. In addition, the post-test scores show that the internal goal regulation scores showed a significant difference in favour of the experimental group, and the test anxiety scores showed a significant difference in favour of the control group.

## Discussion & Conclusion

The question 'Is there a significant difference between EG and CG students' motivation (IGO1, EGO2, TV3, CLB4, SELP5, TA6) according to the teaching method?' takes place in the scope of the research problem; the motivations of the students of the experimental and control groups were examined using statistical methods. MANOVA analysis was used to determine whether there was a significant difference between the motivation pre-test scores of the experimental and control group students.

The results of the MANOVA analysis performed on the scores for the IGO1, EGO2, TV3, CLB4, SELP5 and TA6 sub-dimensions revealed that there was a significant difference between the post-test scores of the experimental and control group students (($\Lambda$) = .700, $F$ (6, 93) = 6.629, $p < .05$) (Varoglu, 2021).

In the present study, the 5E Learning Model was implemented with the support of concept maps. It was concluded that the motivation of the experimental group students for the chemistry lesson was higher in the IGO1 sub-dimension. The TA6 sub-dimension was lower than the control group students. The literature revealed that learning activities prepared with the 5E Learning Model (Aktaş, 2013; Cetin-Dindar & Geban, 2017; Cheng et al., 2015; İlter & Ünal, 2014) and concept maps (Kara & Kefeli, 2018; Keraro et al., 2007) increase the motivation of the students towards the lesson in different courses, such as social studies, science, biology, and chemistry. Moreover, it has been determined that the context-based teaching method supported by the 5E learning model increased student motivation and conceptual understanding in science lessons (Derman & Badeli, 2017). Similarly, it is stated in the literature that the simulation and animation-supported 5E model increases the success and motivation of students in science lessons (Derman & Badeli, 2017; Öner & Yaman, 2020).

Based on the results, although the mean scores of EGO2, TV3, CLB4 and SELP5 were higher for the experimental group students than the control group students, there was no significant difference between the two groups. In addition, there were significant differences in the IGO1 and TA6 scores between the experimental and control group students. Pintrich et al. (1991) state that there is a negative relationship between test anxiety and academic performance. According to the results, the experimental group students had higher IGO1 mean scores, and the control group had higher TA6 scores. Studies show that intrinsic goal orientation is associated with success as one of the academic outcomes (Pintrich & Schrauben, 1992; Sungur & Gungoren, 2009). Otherwise, the intrinsic goal orientation encourages students to have a more advanced cognitive structure by focusing on learning (Pintrich & Schrauben, 1992)

Considering the results obtained from this study and the findings from the studies conducted in the literature in general, it can be stated that the 5E Learning Model, which is supported by using different techniques, positively affects the success, attitude, and motivation of the students in the course. Furthermore, it is thought that using the constructivist learning models will positively affect students' motivation and attitudes towards lessons by helping them learn information more easily in lessons containing abstract concepts, such as those related to chemistry. Motivation is a variable that explains an individual's behaviour but cannot be directly observed (Korkut & Oren, 2018). Motivation will also improve students' effective learning by supporting their active participation (Korkut & Oren, 2018). The findings determined that, except for the IGO1 and TA6 components, the motivation dimensions did not show a significant difference between the experimental and control groups. It is thought that this result may be due to reasons such as the 8$^{th}$-grade students' difficulties in understanding the chemistry lesson because it contains abstract concepts, the insufficient duration of the application, and their prejudices against different learning methods, techniques, and strategies. In this context, applying the 5E Learning Model Improved with Concept Maps in different topics of chemistry is recommended; different variables, such as prejudices and attitudes towards the lesson, as well as students' motivations, should be examined in future studies. From this point of view, considering the results of this study, all dimensions of motivation should be developed while preparing the activities in practice.

It is thought that the findings of this study are significant in terms of the classroom environment. The study concluded that the 5E learning model improved with concept maps is an effective method for increasing student motivation. The concept maps improved students' motivation towards learning chemistry by helping them visualise and organise their knowledge. Additionally, the inclusion of games, puzzles, and other interesting activities within the scope of this study made learning enjoyable and heightened the interest of students in the learning environment. However, it was also observed that the students with an intrinsic goal orientation were more motivated to learn chemistry. These students were motivated by the learning process rather than external rewards such as grades. In this context, teachers must provide students opportunities to explore new concepts and offer focused feedback on their progress and understanding.

Another finding of the study is that the 5E learning model improved with concept maps reduces students' test anxiety. This model enables students to develop their knowledge and skills gradually while practising in a supportive environment. To address this anxiety, teachers should establish a supportive and encouraging environment and provide opportunities for students to practice their skills in preparation for exams.

The main limitation of the presented study is that the students could not be selected randomly: the existing classes were used. To minimise this limitation, the existing classes were chosen randomly. Additionally, the study was conducted within the framework of the subject of the periodic table. It is believed that the long-term application of this model to other chemistry subjects will further impact students' motivation.

## Research ethics

All procedures performed in studies involving human participants were in accordance with the ethical standards of Hacettepe University's ethical committee, and the committee approved the data collection procedures. The study was also conducted under the following ethical standards: Ethics

Committee's Decision Date: 25.01.2019, Ethics Committee Approval Issue Numbers: 51944218-300/00000431740.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## References


Abd El-Hay, S. A., El Mezayen, S. E., & Ahmed, R. E. (2018). Effect of concept mapping on problem-solving skills, competence in clinical setting and knowledge among undergraduate nursing students. *Journal of Nursing Education and Practice*, *8*(8), 34-46. https://doi.org/10.5430/jnep.v8n8p34

Aguiar, J. G., & Correia, P. R. (2016). Using concept maps as instructional materials to foster the understanding of the atomic model and matter–energy interaction. *Chemistry Education Research and Practice*, *17*(4), 756-765. https://doi.org/10.1039/C6RP00069J

Akbaba, S. (2006). Eğitimde motivasyon [Motivation in education]. *Journal of Kazım Karabekir Education Faculty*, (13), 343-361.

Akgunduz, D., & Bal, Ş. (2013). The usage of concept maps for the biology subject in the 6th grade of science lesson in primary school and determination of their effect toaa the student's behaviour and academical success. *21. Yüzyılda Eğitim ve Toplum Eğitim Bilimleri ve Sosyal Araştırmalar Dergisi[Journal of Education and Social Educational Sciences and Social Research in the 21st Century]*, *2*(5), 86-96.

Aktaş, M. (2013). The effect of the 5E learning model and cooperative learning method on attitude toward biology lesson. *Gazi University Journal of Gazi Educational Faculty (GUJGEF)*, *33*(1), 109-128.

Alkan, İ., & Bayri, N. (2017). A meta analysis study on the relationship between motivation for science learning and science achievement. *Dicle University Journal of Ziya Gökalp Faculty of Education*, *32*, 865-874. https://doi.org/10.14582/DUZGEF.1853

Altun, S., & Erden, M. (2006). Öğrenmede motive edici stratejiler ölçeğinin geçerlik ve güvenirlik çalışması [Validity and reliability study of the scale of motivating strategies in learning]. *Yeditepe Üniversitesi Edu7[Edu 7:Yeditepe University]*, *2*(1), 1-16.

Atay, A. D. (2014). *Investigation on secondary school students' motivation levels and metacognitive awareness on learning science.* (Publication No. 372569) [Master's thesis, Adnan Menderes University]. Council of Higher Education (CoHE) Thesis Center.

Atkin, J. M., & Karplus, R. (1962). Discovery or invention?. *The Science Teacher, 29*(5), 45-51. http://www.jstor.org/stable/24146536

Austin, A. C., Hammond, N. B., Barrows, N., Gould, D. L., & Gould, I. R. (2018). Relating motivation and student outcomes in general organic chemistry. *Chemistry Education Research and Practice*, *19*(1), 331-341. https://doi.org/10.1039/C7RP00182G

Austin, L. B., & Shore, B. M. (1995). Using concept mapping for assessment in physics. *Physics Education*, *30*(1), 41-45. https://doi.org/10.1088/0031-9120/30/1/009

Aydin, S. (2016). An analysis of the relationship between high school students' self-efficacy, metacognitive strategy use and their academic motivation for learn biology. *Journal of Education and Training Studies*, *4*(2), 53-59. http://dx.doi.org/10.11114/jets.v4i2.1113

Azizoğlu, N., & Çetin, G. (2009). Six and seventh grade students' learning styles, attitudes towards science and motivations. *Kastamonu Education Journal*, *17*(1), 171-182.

Bagci, H., & Yalin, H. İ. (2018). The effects of 5E learning cycle model in adaptive blended learning environment to students' academic success. *Journal of Theoretical Educational Science, 11*(3), 562-585. https://doi.org/10.30831/akukeg.382522

Bektuzun, B., & Yel, M. (2019). The effect of teaching with concept map in the subject of classification of living things and biological diversity on academic achievement of the 9th grade students. *Gazi University Journal of Gazi Educational Faculty (GUJGEF)*, *39*(1), 91-113. https://doi.org/10.17152/gefad.439037

Bulut, L., Oluk, N. T., & Ekmekci, G. (2021). Determining chemistry teacher candidates' misconceptions about solutions and dissolution with concept maps. *Gazi University Journal of Gazi Educational Faculty (GUJGEF), 41*(3), 1359-1407.

Büyüköztürk, S., Akgün, Ö. E., Özkahveci, Ö., & Demirel, F. (2004). The validity and reliability study of the Turkish version of the motivated strategies for learning questionnaire. *Educational Sciences: Theory & Practice*, *4*(2), 231-239.

Bybee, R., Taylor, J. A., Gardner, A., van Scotter, P., Carlson, J., Westbrook, A., Landes, N., Spiegel, S., McGarrigle Stuhlsatz, M., Ellis, A., Resch, B., Thomas, H., Bloom, M., Moran, R., Getty, S., Knapp, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Colorado Springs CO: BSCS. https://media.bscs.org/bscsmw/5es/bscs_5e_full_report.pdf

Cetin-Dindar, A., & Geban, Ö. (2015). Adaptation of the science motivation scale into Turkish and chemistry: Analysis of validity. *Pegem Journal of Education and Instruction, 5*(1), 15-34. https://doi.org/10.14527/pegegog.2015.002

Cetin-Dindar, A., & Geban, O. (2017). Conceptual understanding of acids and bases concepts and motivation to learn chemistry. *The Journal of Educational Research*, *110*(1), 85-97. https://doi.org/10.1080/00220671.2015.1039422

Chawla, J., & Singh, G. (2015). Effect of concept mapping strategy on achievement in chemistry of ix graders in relation to achievement motivation. *Asia Pacific Journal of Research*, *18*(24), 53-65.

Chen, C. H., Chou, Y. Y., & Huang, C. Y. (2016). An augmented-reality-based concept map to support mobile learning for science. *The Asia-Pacific Education Researcher*, *25*, 567-578.

Cheng, P. H., Yang, Y. T. C., Chang, S. H. G., & Kuo, F. R. R. (2015). 5E mobile inquiry learning approach for enhancing learning motivation and scientific inquiry ability of university students. *IEEE Transactions on Education*, *59*(2), 147-153. https://doi.org/10.1109/TE.2015.2467352

Chiou, C. C. (2015). The comparative effect of computer-assisted and paper-and-pencil concept mapping on learning motivation and achievement. *International Journal of Information and Education Technology*, *5*(9), 668-671. https://doi.org/10.7763/IJIET.2015.V5.589

Chyung, S. Y., Moll, A. J., & Berg, S. A. (2010). The role of intrinsic goal orientation, self-efficacy, and e-learning practice in engineering education. *Journal of Effective Teaching*, *10*(1), 22-37.

Çeliker, H. D., Tokcan, A., & Korkubilmez, S. (2015). Does motivation toward science learning affect scientific creativity? *Mustafa Kemal University Journal of Social Sciences Institute*, *12*(30), 167-192.

Çömek, A., Akınoğlu, O., Elmacı, E., & Gündoğdu, T. (2016). The effect of concept mapping on students' academic achievement and attitude in science education. *Journal of Human Sciences*, *13*(1), 348-363. https://doi.org/10.14687/ijhs.v13i1.3558

Demir, Y., & Emre, İ. (2020). The effect of learning activities based on 5e learning model on 4thgrade science teaching. *Mersin University Journal of the Faculty of Education*, *16*(3), 573-586. https://doi.org/10.17860/mersinefd.750957

Demircioğlu, H., Aslan, A., Açıkgöz, D., Karababa, Y., & Güven, O. (2019). The effect of react strategy on the students' academic achievements and motivations. *Journal of International Social Research*, *12*(64), 547-561. http://dx.doi.org/10.17719/jisr.2019.3377

Derman, A., & Badeli, Ö. (2017). The investigation of the impact of the context-based teaching method supported by the 5E model in teaching 4th grade students the "pure material and mixture" topic on the students' conceptual perceptions and their attitude towards science. *Bolu Abant İzzet Baysal University Journal of Faculty of Education*, *17*(4), 1860-1881. https://doi.org/10.17240/aibuefd.2017.17.32772-363969

Eskicioglu, A. P., & Alpat, Ş. (2017). Development of chemistry lesson motivation scale for secondary school students. *Journal of the Turkish Chemical Society Section C: Chemical Education*, *2*(2), 185-212.

Ferrell, B., Phillips, M. M., & Barbera, J. (2016). Connecting achievement motivation to performance in general chemistry. *Chemistry Education Research and Practice*, *17*(4), 1054-1066. https://doi.org/10.1039/C6RP00148C

Garver, M. S., & Mentzer, J.T. (1999). Logistics research methods: Employing structural equation modeling to test for construct validity. *Journal of Business Logistics, 20*(1), 33-57.

George, J. K. & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference*. 11.0 update (4th Ed.), Allyn & Bacon.

Gunes Yazar, O., & Nakiboglu, C. (2020). Investigation of vocational and technical Anatolian high school students' chemistry motivation level changes based on their fields: A longitudinal study. *Journal of the Turkish Chemical Society Section C: Chemical Education*, *5*(2), 183-204. https://doi.org/10.37995/jotcsc.793248

Guven, G., Kozcu Cakir, N., Sulun, Y., Cetin, G., & Guven, E. (2022). Arduino-assisted robotics coding applications integrated into the 5E learning model in science teaching. *Journal of Research on Technology in Education*, *54*(1), 108-126. https://doi.org/10.1080/15391523.2020.1812136

Güngör Seyhan, H. (2020). An investigation of high school students' motivation towards chemistry lesson, attitude towards chemistry lesson, self-efficacy levels and self-regulatory learning strategies in terms of some variables: Sivas province. *The Educational Science and Research Journal*, *1*(1), 32-56.

Iyer, D.N., Sharp, B.M. & Brush, T.H. (2017). Knowledge creation and innovation performance: An exploration of competing perspectives on organizational systems. *Universal Journal of Management, 5*(6), 261 270. https://doi.org/10.13189/ujm.2017.050601

İlter, İ., & Ünal, Ç. (2014). The effect of the activities based on 5E learning cycle model on learning process in social studies teaching: An action research. *The Journal of Turkish Social Research*, *181*(181), 295-330.

Kallner, A. (2018). *Laboratory statistics*. Elsevier.

Kara, F., & Kefeli, N. (2018). The effect of using concept maps on student's success, logical thinking and attitudes towards science. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *12*(2), 594-619. https://doi.org/10.17522/balikesirnef.506475

Karadeniz, S., Büyüköztürk, S., Akgün, O. E., Çakmak, E. K., & Demirel, F. (2008). The Turkish adaptation study of Motivated Strategies for Learning Questionnaire (MSLQ) for 12-18 year old children: Results of confirmatory factor analysis. *The Turkish Online Journal of Educational Technology, 7*(4), 108-117.

Karpudewan, M., Roth, W. M., & Ismail, Z. (2015). The effects of "Green Chemistry" on secondary school students' understanding and motivation. *The Asia-Pacific Education Researcher*, *24*(1), 35-43. https://doi.org/10.1007/s40299-013-0156-z

Keraro, F. N., Wachanga, S. W., & Orora, W. (2007). Effects of cooperative concept mapping teaching approach on secondary school students' motivation in biology in Gucha district, Kenya. *International Journal of Science and Mathematics Education*, *5*(1), 111-124. https://doi.org/10.1007/s10763-005-9026-3

Kian, T., Yusoff, W., & Rajah, S. (2014). Motivation for generations' cohorts: An organizational justice perspective. *International Journal of Management Sciences*, *11*(2), 536-542.

Kilic, M., & Cakmak, M. (2013). Concept maps as a tool for meaningful learning and teaching in chemistry education. *International Journal on New Trends in Education and their Implications*, *4*(4), 152-164.

Koc, R. S. G., & Sarikaya, M. (2020). The effect of the 5E learning model and the context based teaching method on achievement and permanence towards subject of light. *e-Kafkas Journal of Educational Research*, *7*(3), 430-457. https://doi.org/10.30900/kafkasegt.828542

Korkut, T. Y., & Oren, F. Ş. (2018). The effect of the science stories' supported with concept cartoons on the academic achievement, attitude and motivation. *Western Anatolia Journal of Educational Sciences, 9*(1), 38-52.

Kostova, Z., & Radoynovska, B. (2010). Motivating students' learning using word association test and concept maps. Bulgarian Journal of Science & Education Policy, *4*(1), 62–98.

Kutu, H., & Sözbilir, M. (2011). Teaching "chemistry in our lives" unit in the 9th grade chemistry course through context-based ARCS instructional model. *Ondokuz Mayis University Journal of Education Faculty*, *30*(1), 29-62.

Lin, Y. G., McKeachie, W. J., & Kim, Y. C. (2003). College student intrinsic and/or extrinsic motivation and learning. *Learning and Individual Differences*, *13*(3), 251-258. https://doi.org/10.1016/S1041-6080(02)00092-4

Lynch, D. J., & Trujillo, H. (2011). Motivational beliefs and learning strategies in organic chemistry. *International Journal of Science and Mathematics Education*, *9*(6), 1351-1365. https://doi.org/10.1007/s10763-010-9264-x

Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching*, *27*(10), 937-949. https://doi.org/10.1002/tea.3660271003

Orcan, F. (2020). Parametric or non-parametric: Skewness to test normality for mean comparison. *International Journal of Assessment Tools in Education*, *7*(2), 255-265. https://doi.org/10.21449/ijate.656077

O'Rourke, N., Hatcher, L., & Stepanski E. J. (2005). *A step-by-step approach to using SAS for univariate and multivariate statistics* (2nd ed.). SAS Institute Inc.

Ozgun, B. B. G., & Yalcin, F. S. (2019). Concept maps for the general biology course on the effects of academic achievement and attitude. *Kastamonu Education Journal*, *27*(3), 1149-1162. https://doi.org/10.24106/kefdergi.2724

Öner, Y. E., & Yaman, S. (2020). The effect of simulation and animation supported 5E model on science achievement and motivation of prospective classroom teachers. *Turkish Journal of Primary Education*, *5*(2), 183-193.

Perry, J.L., Dempster, M. & McKay, M.T. (2017) Academic self-efficacy partially mediates the relationship between Scottish index of multiple deprivation and composite attainment score. *Frontiers in Psychology, 8*, 1-9. https://doi.org/10.3389/fpsyg.2017.01899

Pintrich, P. R. (1999). The role of motivation in promoting and sustaining self-regulated learning. *International Journal of Educational Research*, *31*(6), 459-470. https://doi.org/10.1016/S0883-0355(99)00015-4

Pintrich, P., & García, T. (1993). Intraindividual differences in students' motivation and self-regulated learning. *German Journal of Educational Psychology*, *7*(3), 99-107.

Pintrich, P., & Schrauben, B. (1992). Students' motivational beliefs and their cognitive engagement in classroom academic tasks. In D. H. Schunk & J. Meese (Eds.), *Student perceptions in the classroom* (pp. 149–183). Lawrence Erlbaum Associates.

Pintrich, P. R., Smith, D. A. F., Garcia, T. & McKeachie, W. J. (1991) *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Office of Educational Research and Improvement (ED).

Pirci, H. A., & Torun, G. (2020). The effect of 5E learning model on the academic achievement of 6thgrade students in the teaching of algebraic expressions. *Kastamonu Education Journal*, *28*(1), 494-511. https://doi.org/10.24106/kefdergi.3688

Putra, F., Nur Kholifah, I. Y., Subali, B., & Rusilowati, A. (2018). 5E-learning cycle strategy: Increasing conceptual understanding and learning motivation. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *7*(2), 171-181. https://doi.org/10.24042/jipfalbiruni.v7i2.2898

Ries, K. E., Schaap, H., Loon, A. M. M., Kral, M. M., & Meijer, P. C. (2022). A literature review of open-ended concept maps as a research instrument to study knowledge and learning. *Quality & Quantity: International Journal of Methodology*, *56*(1), 73-107. https://doi.org/10.1007/s11135-021-01113-x

Rizki, D., Yusrizal, Y., Halim, A., & Syukri, M. (2023). Application of the 5E Learning Cycle Learning Model to Increase Student Learning Motivation in Sound Wave Material. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 412-416. https://doi.org/10.29303/jppipa.v9i1.2593

Sari, A., & Bayram, H. (2018). Effects of concept mapping and computer assisted instruction on removing 7th grade students' misconceptions on the matter subject. *International Journal of Social Science, 67*, 29-47. http://dx.doi.org/10.9761/JASSS7579

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the fit of structural equation models: Tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research-Online, 8*(2), 23-74.

Schunk, D. H., Pintrich, P. R., & Meece, J. L. (2008). *Motivation in education: Theory, research and application*. Pearson.

Sharaabi-Naor, Y., Kesner, M. ve Shwartz, Y. (2014). Enhancing students' motivation to learn chemistry. *Journal of Education, 2*(2), 100-123. https://doi.org/10.25749/sis.4068

Singh, I. S., & Moono, K. (2015). The effect of using concept maps on student achievement in selected topics in chemistry at tertiary level. *Journal of Education and Practice*, *6*(15), 106-116.

Snetinová, M., Kácovský, P., & Machalická, J. (2018). Hands-on experiments in the interactive physics laboratory: students' intrinsic motivation and understanding. *Center for Educational Policy Studies Journal*, *8*(1), 55-75. https://doi.org/10.25656/01:15481

Sungur, S. (2004). *The implementation of problem based learning in high school biology courses.* (Publication No. 153617) [Doctoral dissertation, Middle East Technical University]. Council of Higher Education (CoHE) Thesis Center.

Sungur, S., & Gungoren, S. (2009). The role of classroom environment perceptions in self-regulated learning and science achievement. *Elementary Education Online*, *8*(3), 883-900.

Şen, Ş. (2015). *Investigation of students' conceptual understanding of electrochemistry and self-regulated learning skills in process oriented guided inquiry learning environment.* (Publication No. 394831) [Doctoral dissertation, Hacettepe University]. Council of Higher Education (CoHE) Thesis Center.

Şen, Ş., & Yılmaz, A. (2014). Investigating high school and university students' motivation towards chemistry: A cross age study. *The Western Anatolia Journal of Educational Sciences*, *5*(10), 17-37.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics*. Pearson.

Talbert, L. E., Bonner, J., Mortezaei, K., Guregyan, C., Henbest, G., & Eichler, J. F. (2020). Revisiting the use of concept maps in a large enrollment general chemistry course: implementation and assessment. *Chemistry Education Research and Practice*, *21*(1), 37-50. https://doi.org/10.1039/C9RP00059C

Tosun, C. (2013). Adaptation of chemistry motivation questionnaire-II to Turkish: A validity and reliability study. *Erzincan University Journal of Education Faculty*, *15*(1), 173-202.

Tosun, C., Şenocak, E., & Özeken, Ö. (2013). The effect of problem-based learning on undergraduate students' motivation to the general chemistry course and scientific process skill levels. *Mersin University Journal of the Faculty of Education*, *9*(3), 99-114.

Tosun, C., & Taşkesenligil, Y. (2012). The effect of problem based learning on student motivation towards chemistry classes and on learning strategies. *Journal of Turkish Science Education*, *9*(1), 104-125.

Utami, D. N., & Subali, B. (2020). 5E learning cycle combined with mind mapping in excretory system: effectiveness on curiosity. *Biosfer: Jurnal Pendidikan Biologi*, *13*(1), 130-142. https://doi.org/10.21009/biosferjpb.v13n1.130-142

Varoglu, L. (2021). *Effect of 5E learning model supported concept maps on students' understanding of chemical concepts.* (Publication No. 685616) [Doctoral dissertation, Hacettepe University]. Council of Higher Education (CoHE) Thesis Center.

Yalcin Altun, S., Açışlı, S., & Turgut, Ü. (2010). The effect of five e instructional model on pre-service science teachers' attitudes towards physics laboratory and development of scientific process skills. *Kastamonu University, Kastamonu Education Journal*, *18*(1), 147-158.

Yıldırım, H. İ., & Kansız, F. (2018). An investigation into the secondary school students' motivation toward science learning. *Cumhuriyet International Journal of Education*, *7*(3), 241-268. https://doi.org/10.30703/cije.423383

Zusho, A., Pintrich, P. R., & Coppola, B. (2003). Skill and will: The role of motivation and cognition in the learning of college chemistry. *International Journal of Science Education*, *25*(9), 1081-1094. https://doi.org/10.1080/0950069032000052207

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