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FOSTERING ACADEMIC INTRINSIC MOTIVATION THROUGH PDEODE-BASED CHEMISTRY LABORATORY ACTIVITIES [1]

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ABSTRACT

This study examines the impact of the PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) method on academic intrinsic motivation in science education. The PDEODE method fosters a meaningful and engaging learning environment through enhancing students' interactions with science. The research was conducted with 38 pre-service science teachers at a public university in Türkiye. Over six weeks, students participated in chemistry laboratory activities based on the PDEODE method, and their motivation levels were assessed before and after implementation using the Academic Intrinsic Motivation Scale (AIM). The findings indicated that PDEODE activities significantly enhance students' academic intrinsic motivation. Statistically significant improvements were detected in the motivational dimensions of need for achievement, perceived expertise, and social acceptance. Additionally, laboratory activities facilitated the improvement of students' experimental skills, reinforced their self-confidence, and encouraged a more positive attitude toward failure. The discussion stages were found to encourage students to express their thoughts more confidently, thereby strengthening their motivation. In conclusion, the PDEODE method emerges as an effective instructional model that not only enhances students' scientific thinking skills but also increases their motivation. This study highlights PDEODE as an innovative method to science education and offers insights into developing teaching strategies that enhance students' engagement with scientific concepts.

Keywords: Academic intrinsic motivation, chemistry laboratory activities, PDEODE method, science education, university students.

TaTGA Destekli Kimya Laboratuvarı Etkinlikleri Yoluyla Akademik İçsel Motivasyonun Güçlendirilmesi

ÖZ

Bu çalışma, TaTGA (Tahmin Et-Tartış-Açıkla-Gözlemle-Tartış-Açıkla) yönteminin fen eğitiminde akademik içsel motivasyon üzerindeki etkisini incelemektedir. TaTGA yöntemi, öğrencilerin fen bilimleriyle etkileşimini artırarak anlamlı ve etkili bir öğrenme ortamı oluşturmaktadır. Araştırma, Türkiye'deki bir devlet üniversitesinde öğrenim gören 38 fen bilgisi öğretmen adayı ile gerçekleştirilmiştir. Altı hafta süresince öğrenciler, TaTGA yöntemine dayalı kimya laboratuvar etkinliklerine katılmış ve motivasyon seviyeleri uygulama öncesinde ve sonrasında Akademik İçsel

[1] This study is based on the master's thesis entitled *Evaluation of Academic Achievement Performance and Academic Intrinsic Motivation of University Students Through PDEODE Tasks*, submitted under the supervision of Prof. Dr. Melis Arzu Uyulgan on January 31, 2023.

Motivasyon Ölçeği (AİM) kullanılarak değerlendirilmiştir. Bulgular, TaTGA etkinliklerinin öğrencilerin akademik içsel motivasyonunu önemli ölçüde artırdığını göstermektedir. Özellikle başarı ihtiyacı, uzmanlık algısı ve sosyal kabul boyutlarında istatistiksel olarak anlamlı gelişmeler tespit edilmiştir. Ayrıca, laboratuvar etkinliklerinin öğrencilerin deneysel becerilerini geliştirdiği, öz güvenlerini pekiştirdiği ve başarısızlığa karşı daha olumlu bir tutum geliştirmelerini teşvik ettiği belirlenmiştir. Tartışma aşamalarının, öğrencilerin düşüncelerini daha özgüvenli bir şekilde ifade etmelerini sağladığı ve böylece motivasyonlarını güçlendirdiği tespit edilmiştir. Sonuç olarak, TaTGA yöntemi, öğrencilerin bilimsel düşünme becerilerini geliştiren ve motivasyonlarını artıran etkili bir öğretim modeli olarak öne çıkmaktadır. Bu çalışma, TaTGA yöntemini fen eğitiminde yenilikçi bir yöntem olarak vurgulamakta ve öğrencilerin bilimsel kavramlarla etkileşimini güçlendiren yenilikçi öğretim stratejilerinin geliştirilmesine yönelik önemli çıkarımlar sunmaktadır.

Anahtar Kelimeler: Akademik içsel motivasyon, kimya laboratuvar uygulamaları, TaTGA yöntemi, fen eğitimi, üniversite öğrencileri.

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INTRODUCTION

Achieving success becomes challenging when emotional factors are overlooked, as there is a strong interplay between cognitive and emotional dimensions in learning (Duit & Treagust, 2003). Contemporary educational approaches that recognize this relationship have increasingly focused on enhancing learners' cognitive outcomes and positively influencing their emotional outcomes. Motivation, an essential emotional dimension, is defined as the driving force that initiates and directs behavior (Di Serio, Ibáñez, & Kloos, 2013). Research has shown a positive correlation between students' motivation and their academic achievement (Napier & Riley, 1985; Tuan, Chin, & Shieh, 2005). Students who are motivated to learn science are generally expected to perform better than those who lack such motivation. In this context, the learning environment plays a crucial role in shaping students' motivation towards science learning (Tuan, Chin, & Shieh, 2005; Wang & Reeves, 2007). Recent studies have emphasized the importance of interactive and student-centered learning environments for enhancing students' science learning motivation. For example, inquiry-based learning environments in science laboratories have been shown to promote student motivation by engaging learners both hands-on and minds-on activities (Hofstein & Lunetta, 2004; Lord, 2001). Laboratory experiences allow students to actively construct their knowledge, develop scientific skills, and experience the process of scientific inquiry firsthand. This practical engagement fosters a deeper understanding of scientific concepts and helps to maintain interest and motivation in science learning (Hofstein & Mamlok-Naaman, 2007).

Furthermore, one of the recent researches suggests that laboratory-based science education can significantly impact students' affective outcomes, including motivation, interest, and attitudes toward science (Abrahams & Reiss, 2012). A well-designed laboratory learning environment not only provides cognitive benefits but also positively influences students' emotional experiences by making learning more meaningful and enjoyable. When students are given opportunities to explore scientific phenomena through experiments, they tend to exhibit higher levels of engagement and intrinsic motivation, which contribute to greater learning success (Bennett, Lubben, & Hogarth, 2007).

In addition, the affective benefits of laboratory-based instruction can be enhanced by incorporating elements such as collaborative learning and real-life problem-solving tasks. Studies have indicated that when students collaborate in laboratory settings, they are more likely to develop positive attitudes towards science and demonstrate increased motivation (Hofstein & Lunetta, 2004). In particular, connecting laboratory experiments to real-world issues can make the learning experience more relevant and motivating for students, thus increasing their willingness to persist in science-related tasks (Abrahams, Reiss, & Sharpe, 2013). These findings underscore the need for science educators to create laboratory learning environments that prioritize not only cognitive outcomes but also affective dimensions. By fostering students' motivation through engaging laboratory activities, educators can help students develop a more positive attitude towards science, leading to sustained interest and improved academic performance in the subject.

The Prediction-Observation-Explanation (POE) is a powerful instructional method designed to deepen students' understanding of scientific concepts by actively engaging them in a three-step learning process: prediction, observation, and explanation. In this method, students are first encouraged to predict the outcome of an event or experiment based on their prior knowledge and experiences, justifying their predictions to make their thought processes explicit. They then observe the actual results, allowing them to compare these with their initial predictions, and finally, they reconcile any difference by developing explanations that account for these outcomes. Through this structured method, students may have the opportunity to learn independently at first, and over time, they can perceive the ideas or understandings that may be agreed upon by the entire class. The POE method not only promotes independent thinking but also increases cognitive engagement and motivation by encouraging active participation and critical reflection (Çırakoğlu, Toksoy, & Reisoğlu, 2022). By engaging students through a structured process of prediction, observation, and explanation, POE encourages an intrinsic curiosity that is essential for meaningful learning experiences. Through this method, students are not merely passive recipients of information; instead, they become active participants in their own learning, which inherently boosts motivation as they see themselves contributing to the discovery of knowledge (Nalkıran & Karamustafaoğlu, 2020). As students work through the cycle of prediction, observation, and explanation, they strengthen their critical thinking skills, which can have a positive impact on their achievement and attitudes towards science (Gernale, Duad, & Arañes, 2015).

The POE method begins with the prediction phase, where students are prompted to make educated guesses about the outcome of a given problem or experiment. This phase is particularly effective in sparking interest and motivation, as it requires students to actively engage with their prior knowledge and assumptions. Making predictions offers students a sense of ownership and personal investment in the learning process, which is often associated with higher levels of intrinsic motivation. Additionally, the prediction phase allows students to express their individual ideas and perspectives, reinforcing a personalized learning experience that is motivating and empowering.

In the observation phase, students test their predictions through practical experiments or hands-on activities, which make abstract concepts more comprehensible and concrete. This active involvement not only enhances their understanding but also fosters a sense of achievement and satisfaction, as students witness the outcomes of their predictions unfold in real time. The opportunity to verify or modify their initial assumptions based on observed results enhances students' sense of competence and capability, thereby supporting self-efficacy, a key component of motivation.

The final stage, explanation, prompts students to analyse and interpret their observations in the context of science concepts. This reflective process solidifies their learning and encourages critical thinking, while also reinforcing a deeper understanding of the subject matter. The opportunity to explain their observations provides students with a sense of accomplishment and contributes to sustained motivation, as they see the direct impact of their efforts on their understanding of complex topics.

This study extends this model with an additional "discussion" component, resulting in the PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) framework. This extended method aims to further support student motivation and curiosity by allowing students to discuss the consequences of observed events in more depth. By integrating hands-on activities, laboratory experiments and real-world problem-solving tasks, POE and PDEODE foster a learning environment that is both meaningful and stimulating, increasing students' intrinsic motivation and engagement with science. According to Self-Determination Theory (Deci & Ryan, 1985), the fulfilment of the need for autonomy can significantly enhance intrinsic motivation, particularly when students feel a sense of volition and control over their learning process. In parallel, the theory of need for achievement posits that individuals are naturally driven to seek out new challenges, which enhances their sense of competence. The PDEODE method aligns with these theoretical frameworks by allowing students to make predictions, observe scientific phenomena, and construct explanations based on their own reasoning. This approach fosters autonomy, promotes cognitive engagement, and develops competence—three critical elements that enhance academic intrinsic motivation, particularly in the context of science education.

This research contributes to the field of science education by introducing an innovative method that leverages the PDEODE (Predict-Discuss-Explain-Observe-Discuss-Explain) model to enhance students' intrinsic motivation and comprehension of complex scientific concepts. By employing PDEODE-based student worksheets, the study aims to foster an engaging learning environment that encourages active participation, critical thinking, and collaborative exploration of scientific phenomena. Unlike traditional methods, which may not fully address students' emotional and cognitive needs, this method integrates interactive, student-centered activities designed to promote both cognitive and affective outcomes, making science learning more meaningful and motivating for students.

The novelty of this research lies in combining established POE principles with additional discussion components, forming the PDEODE model to better support students' curiosity and sustained engagement. Recognizing that intrinsic motivation and an interest in science are essential for academic success, this study provides both a theoretical framework and practical guidance for educators in designing effective, motivation-enhancing learning experiences. It also aims to explore the underlying mechanisms through which PDEODE-based worksheets can improve students' motivation and science achievement, thus offering valuable insights for the development of more effective and efficient science teaching strategies. Notably, PDEODE-based activities encourage students to communicate and justify their ideas, creating an interactive environment that promotes motivation through peer discussions and collaborative learning (Dipalaya & Corebima, 2016; Lathifa, 2018). Additionally, PDEODE's constructivist design is shown to increase student motivation by actively involving them in each step of the learning process, where they predict outcomes, discuss these with peers, and revise their understanding based on observations and further discussion (Kolari, Savander-Ranne, & Tiili, 2005).

In this context, the study's primary aim is to elucidate the impact of PDEODE activities on science students' intrinsic academic motivation and related factors and to uncover the mechanisms and reasons behind these changes. By investigating how this method influences students' intrinsic motivation and engagement with scientific content, this study aspires to make a meaningful contribution to the advancement of innovative and effective science teaching practices, aligning with modern educational and pedagogical trends to improve science education quality comprehensively. This study aims to address the following research questions:

- To what extent do PDEODE activities foster science students' academic intrinsic motivation within the context of chemistry experiments?
- What are the students' opinions regarding the impact of the PDEODE activities, as implemented in chemistry experiments, on their academic intrinsic motivation?

METHOD

Research Design

In this study, both qualitative and quantitative data collection instruments were employed to examine changes in the academic intrinsic motivation of the students. The aim was to accurately convey the knowledge expected to be learned in the chemistry laboratory experiments, and an explanatory case study design was chosen. Explanatory case studies are particularly suitable for investigating causal relationships and for exploring complex processes that cannot be adequately explained by experimental or survey methods (Yin, 2003). In such studies, researchers seek to answer "why" and "how" questions, offering explanations about various variables related to individuals or groups, providing detailed information regarding potential scenarios, and in educational research, also examining the process and its impact on the research group, with case studies being used when research questions focus on the process, allowing for a context-dependent analysis (Rose, Spinks, & Canhoto, 2015).

Participants

The study was conducted with 38 first-year students enrolled in a Chemistry 2 course at the Science Education Department of a public university in west part of Türkiye, during the Spring semester of 2020-2021. The sample was purposively selected. Of these students, 7 were male and 31 were female. Purposeful sampling allows for the selection of individuals or groups believed to have in-depth knowledge of the subject matter, enabling a thorough examination of the phenomenon (Cresswell & Plano Clark, 2011).

Participants were introduced to the PDEODE method for the first time in this study. Additionally, the chemistry subjects and experiments covered in this research were being learned by them for the first time as part of the Chemistry 2 course. As first-year students, they had only completed the Chemistry 1 course, which did not include any of the subjects or experiments addressed in this study.

Research Procedure

The research process was conducted over a total of nine weeks. The activities carried out during this period and the data collection instruments used are presented in Figure 1. Between the 2nd and 7th weeks of the study, a specific experimental activity was conducted each week. In the first week, students completed the pre-test of the Academic Intrinsic Motivation Scale and were introduced to the PDEODE method. An introductory session was held to explain the stages of the PDEODE method, supported by a sample experimental activity that was not included in the actual data collection process. This sample experiment was implemented using the PDEODE method and designed worksheets, allowing students to become familiar with the instructional method through active participation. From the second to the seventh weeks, a different chemistry experiment aligned with the PDEODE method was conducted each week. These experiments covered fundamental chemistry concepts such as solubility, heat exchange, crystallization, titration, water hardness determination, and electrolysis. Each experimental activity was carried out with active student participation and in accordance with the stages of the PDEODE method.

Due to the Covid-19 pandemic, the implementation phase of the study was conducted through distance education. Lessons were delivered synchronously on an online education platform where all students were registered with their student numbers and names. The activities took place within the scope of the Chemistry II course, which, according to the curriculum, consists of two theoretical and two practical course hours per week. The PDEODE activities were implemented during the two-hour practical sessions. In these sessions, students actively participated in the activities and discussions by providing verbal contributions. A short time (3-5 minutes) was allocated for students to complete each section of the worksheets, during which they were encouraged to provide real-time feedback to the researchers. Since face-to-face laboratory work was not possible during the pandemic, the experiments were recorded in advance by the researchers. These video recordings were shown to students during the practical hours of the Chemistry II course. Using screen-sharing tools, the researchers explained the stages of the PDEODE method and the overall research process during live online sessions. In this context, the experimental activities were conducted virtually, and students were guided step-by-step through the learning process using visual and interactive materials.

In the eighth week, the post-test of the Academic Intrinsic Motivation Scale was administered, followed by a general evaluation of the process. In the ninth week, structured interview forms were used to collect students' feedback on the research process. Changes in students’ academic intrinsic motivation were examined using both quantitative and qualitative data. Perspectives on the research process were analysed within the framework of themes and sub-themes and were supported by direct quotations.

Limitation of the study is that students participated in the learning process by watching recorded experiment videos instead of conducting the experiments directly in the laboratory. This may have limited their practical experience and interaction with the experiments. However, since the research focused on the impact of the PDEODE method on students' academic intrinsic motivation, the contribution of the activities to motivational changes was evaluated.

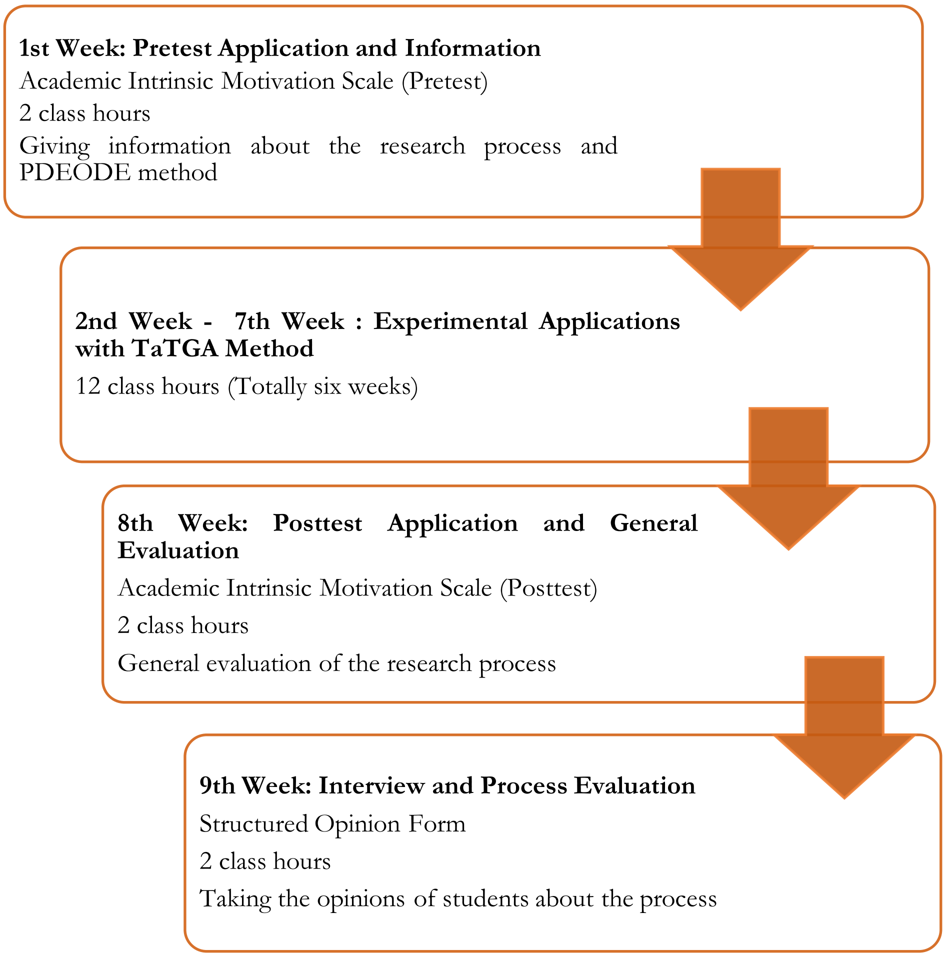

Figure 1. The Research Procedure

Data Collection Tools

Academic Intrinsic Motivation (AIM) Scale

To assess students' academic intrinsic motivation and analyse the factors influencing this motivation, the Academic Intrinsic Motivation Scale developed by Uyulgan and Akkuzu (2014) was employed in the study. This scale, consisting of 23 items, is rated on a 7-point Likert scale ranging from "1 = does not describe me at all" to "7 = describes me completely." The scale comprises four sub-factors: social acceptance (SOA), need for achievement (NFA), expertise (EXP), and fear of failure (FOF). Higher scores on these sub-factors indicate higher levels of academic intrinsic motivation in students. The scale was administered to the sample twice: at the beginning and end of the PDEODE activities. Motivation was chosen as a variable in the study due to its sensitivity to short-term changes. The Cronbach's alpha (α) reliability coefficient of the scale was calculated as 0.769.

Structured Interview Form

A structured interview form developed by the researchers was used to evaluate the impact of PDEODE-based chemistry laboratory activities on students' motivation. In developing the interview form, a question pool was created considering the sub-factors of the AIM scale related to laboratory activities conducted with the PDEODE. A structured interview form consisting of four open-ended questions was prepared based on the opinions of experts and researchers.

Examples of the questions included: *"How did the chemistry experiments conducted with the PDEODE instructional method affect your need for achievement, in terms of accomplishing a task and aiming for better performance?"* and *"How did the chemistry experiments conducted with the PDEODE instructional method influence your individual efforts in terms of* *utilizing your own knowledge, strength, and abilities?"*

All students in the sample answered the questions voluntarily on the form after completing the PDEODE activities. Prior to data collection, ethical approval was obtained from the University Rectorate's Legal Consultancy Office. The qualitative data obtained from this interview form was used to support the quantitative data obtained from the AIM scale.

Data Analysis

Analysis of the AIM Scale

Each item on the Academic Intrinsic Motivation (AIM) scale is scored on a scale from 1 to 7. Based on the responses given by students to the scale items, their scores were calculated, and the total scale score was determined. Since the scale consists of 23 items, the minimum possible score is 23, while the maximum score is 161. Before analysing the data, the normality of the distribution was examined. For the normality test, the Kolmogorov-Smirnov test was applied (since the sample size was greater than 30), and skewness and kurtosis values were assessed (Büyüköztürk, 2013). The results of the pre-test and post-test skewness, kurtosis, and normality tests for the AIM scale are presented in Table 1.

Table 1. Summary of the Skewness, Kurtosis, and Normality Tests

	N	Skewness	Kurtosis	Statistics	df	p
Pre-Test	38	.007	-0.924	.087	37	.200
Post-Test	38	-.841	1.124	.115	37	.185

Considering Table 1, it is observed that the pre-test statistical results for the AIM scale yielded $p = .200$ ($p>.05$), while the post-test statistical results yielded $p = .185$ ($p>.05$). Since the calculated p-values are greater than .05, it indicates that the Kolmogorov-Smirnov test supports the assumption of normal distribution. Additionally, the skewness and kurtosis values falling within the range of -2 to +2 further confirm the normality of the distribution (George & Mallery, 2019).

To determine whether the chemistry laboratory experiment activities developed based on the PDEODE method had a significant impact on students' academic intrinsic motivation throughout the process, the SPSS (Statistical Package for Social Sciences) 21 software was used. The pre-test and post-test total scores obtained from the AIM scale were analysed using the paired-samples t-test. The paired samples t-test is a parametric technique used to compare the significance of the difference between the means of two related samples.

Analysis of the Structured Interview Form

Following the implementation of the experimental activities developed based on the PDEODE method, students' verbal responses to the questions in the structured interview form were transcribed. These transcripts were examined in detail, and the data were analysed using a descriptive approach (Yıldırım & Şimşek, 2016). In the descriptive analysis technique, all data were first read by the researcher and a field expert. In the next stage, the analysts independently categorized the responses into themes and sub-themes. Subsequently, consensus was reached through discussion, and the finalized themes and sub-themes were presented under specific headings, accompanied by direct excerpts from student responses. Student excerpts were coded as S1, S2, …, S38. These excerpts were then interpreted.

To ensure the reliability of the analysis, the formula "Reliability = Agreement / (Agreement + Disagreement) × 100" was applied (Miles & Huberman, 1994). The reliability between the researcher and the field expert was calculated as 97%.

FINDINGS

Findings about the Effects of the PDEODE on the Academic Intrinsic Motivation

In order to assess the possible effects of the PDEODE activities on students' academic intrinsic motivation, the AIM scale was administered to the subjects both before and after the activities. Within-group comparisons between pre-test and post-test scores, as well as comparisons based on the sub-factors of the AIM scale, were analysed using a paired samples t-test. A p-value of 0.05 or less was considered statistically significant.

Table 2. The Results of the Paired-Sample T-Test for the AIM Scale for the Science Education Students

	Sources		***N***	***M***	***SD***	***df***	***t***	***p****
Sub-factors	NFA	Pre-test	38	30.95	6.28	37	-6.25	.000
		Post-test	38	37.26	3.65			
	EXP	Pre-test	38	20.55	4.87	37	-3.88	.000
		Post-test	38	23.92	2.88			
	SOA	Pre-test	38	27.00	11.05	37	-4.31	.000
		Post-test	38	35.47	5.66			
	FOF	Pre-test	38	17.34	4.54	37	1.89	.066
		Post-test	38	15.58	3.30			
Whole scale	AIM	Pre-test	38	97.95	15.11	37	-6.31	.000
		Post-test	38	115.29	9.89			

*p<0.05.

Table 2 presents the results of the paired-samples t-test for pre-, and post-test AIM scores. The total AIM score significantly increased from a pre-intervention mean of 97.95 to a post-intervention mean of 115.29. These results indicate a significant enhancement in students' academic intrinsic motivation following the implementation of PDEODE activities in chemistry laboratory experiments *($t(37) = -6.309$, $p<.05$)*. Therefore, it can be concluded that these activities had a substantial positive impact on students' motivation.

Furthermore, the post-test mean scores for NFA *($M = 37.26$, $SD = 3.65$)*, EXP *($M = 23.92$, $SD = 2.88$)*, and SOA *($M = 35.47$, $SD = 5.66$)* were all higher than their respective pre-test mean scores—NFA *($M = 30.95$, $SD = 6.28$)*, EXP *($M = 20.55$, $SD = 4.87$)*, and SOA *($M = 27.00$, $SD = 11.05$)*. These differences were statistically significant for NFA *($t(37) = -6.25$, $p<.05$)*, EXP *($t(37) = -3.88$, $p<.05$)*, and SOA *($t(37) = -4.31$, $p<.05$)*, further supporting the positive impact of the PDEODE activities.

To assess the magnitude of this effect, Cohen's d was calculated, yielding a value of 1.024, which represents a large effect size. According to Cohen's (1992) classification, effect sizes of 0.2 are considered small, 0.5 medium, and 0.8 large. Thus, this result indicates that PDEODE activities have a strong effect on enhancing students' academic intrinsic motivation.

Overall, these findings demonstrate that integrating PDEODE activities into chemistry laboratory instruction not only significantly increases students' motivation but also has a meaningful and substantial impact in practice.

Qualitative Findings on Students' Academic Intrinsic Motivation

In this study, the effects of the PDEODE instructional method on students' academic intrinsic motivation were examined in depth using data obtained from the interview form. The results indicate that the method has a significant impact on various themes of motivation and achievement. This instructional method, which enhances students' deep thinking and understanding, may also lead to changes in emotional factors such as the need for achievement and fear of failure.

In this study, the effects of the PDEODE on students' academic intrinsic motivation were analysed under four main themes: need for achievement, fear of failure, expertise, and social acceptance. Students' statements reveal how these themes interact with the PDEODE method and contribute to their individual development. The findings are presented by examining each sub-factor separately. Figure 2 illustrates the distribution of themes, sub-themes, and codes obtained from qualitative data.

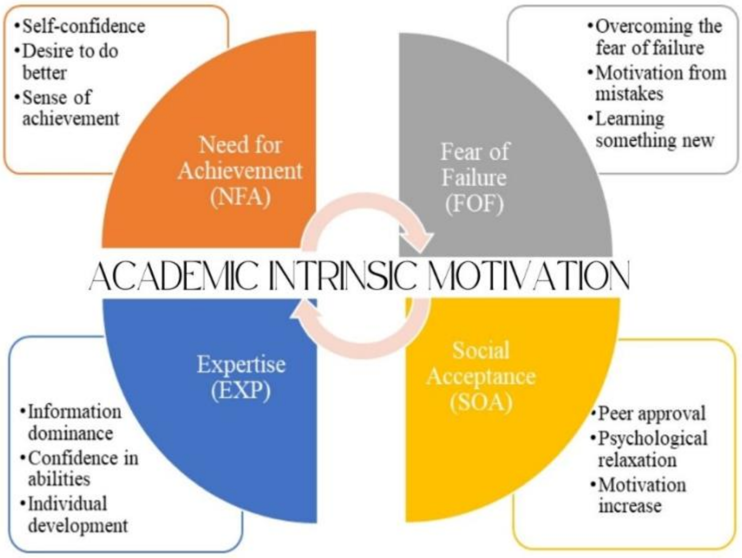

Figure 2. Thematic Map: Major Themes and Sub-themes.

The Theme of Need for Achievement

This theme addresses the impact of the PDEODE on the sub-factor of need for achievement. Most students reported that the PDEODE instilled self-confidence and happiness upon successfully completing a task and fostered a desire to improve further. Some students expressed their thoughts as follows:

> S4: "It helped me conduct more research and identify the most accurate and best solution. Since I regularly completed my assignments through weekly research, I can say that it gave me a sense of accomplishment. I started to examine the adequacy of the information I found more thoroughly. The thought of 'there must be a better way' encouraged me to conduct more research and find different sources."

> S32: "When I made correct predictions, it gave me confidence and happiness in the sense of 'I accomplished this task.' When I made incorrect predictions, it instilled in me the feeling that 'I can do better.' In this respect, it significantly benefited my achievement needs."

The Theme of Fear of Failure

This theme explores the impact of the PDEODE on the fear of failure. In their responses, students generally stated that they experienced a fear of failure before using this method; however, after experiencing it, their fears were alleviated. PDEODE has increased students' motivation for conducting experiments, enhanced their self-confidence, and helped them develop a more positive attitude toward failure. Initially anxious about conducting experiments, students improved their scientific process skills through this method and began to see failure as a learning opportunity. Some students shared the following thoughts on this matter:

> S30: "Before the PDEODE, I experienced a lack of motivation, and I was unsure how to conduct experiments and demonstrate them to my students without firsthand observation. Thanks to the PDEODE, these concerns disappeared. I now possess the necessary experimental knowledge. I can find new experiments, implement them, and discuss them."

> S32: "Yes, I had fears, but after conducting the experiment and understanding the core concept, I motivated myself by thinking, 'Even if I failed, I learned something new today.' In this regard, this method instilled the notion that 'failure is possible, but there is no need to fear it; simply strive to improve."

The Theme of Expertise

This theme examines the impact of the PDEODE on expertise. Upon analysing the responses, students mostly indicated that this method enhanced their subject mastery and increased their confidence in individual studies. Some students expressed the following thoughts:

> S1: "I was able to test my knowledge and make predictions using this strategy. I was able to assess my own skills and knowledge, which strengthened my resolve to put in more effort. "I was inspired to ask myself, 'Why can't I do it?' and to work harder, especially when my peers made predictions that were better and more accurate than mine."

> S30: "Initially, I learned how to apply my knowledge to experiments. I grasped how to interpret experimental results. I realized that I could both conduct and analyse such experiments."

The Theme of Social Acceptance

This theme addresses the impact of the PDEODE on social acceptance. Most responses indicated that classroom discussions conducted using the PDEODE positively influenced students' motivation and self-confidence through the approval and appreciation of their ideas. Some students expressed their thoughts as follows:

> S3: "I felt quite good. After receiving my first approval, I felt more at ease when expressing my next thought. My fear of judgment and making mistakes gradually diminished with each approval and shared perspective, which relieved me."

> S34: "Since others shared my opinions, my self-confidence increased, and my motivation was boosted. Therefore, the PDEODE had a positive impact on social acceptance."

The findings of this study indicate that students experienced both academic and emotional growth through the PDEODE by engaging in more research, achieving success, and overcoming their fear of failure. Additionally, the method supported students' pursuit of social acceptance, enhancing their self-confidence in classroom interactions. Overall, the PDEODE creates a transformative and supportive effect on intrinsic academic motivation. The students' sense of achievement, ability to overcome fear of failure, and steps toward developing expertise demonstrate that this method is an effective instructional method.

DISCUSSION and CONCLUSION

This study aimed to investigate the effect of chemistry laboratory experiments based on the PDEODE method on students' academic intrinsic motivation in the context of chemistry education. The findings indicate that PDEODE activities enhance academic intrinsic motivation among first-year science teacher education students. The results show a significant increase in students' academic intrinsic motivation following their participation in laboratory experiments conducted using the PDEODE method.

The statistical difference between students' academic intrinsic motivation scores before and after the application of PDEODE activities was examined. The results of the study indicated that the use of PDEODE activities in the six-week-long chemistry laboratory experiments positively and statistically significantly affected students' academic intrinsic motivation. Academic motivation plays a crucial role in student success and retention. Research has shown that intrinsic motivation is positively correlated with academic performance and peer teaching activities (Sobral, 2009). Student-centered approaches, by encouraging active participation in the learning process, play an important role in enhancing academic motivation. In this context, PDEODE emerges as an effective strategy in increasing students' interest and motivation for learning while improving their cognitive and communication skills.

PDEODE, being based on the core principles of the POE method, offers students opportunities to freely express their thoughts, interact with peers, and learn through observation. Numerous studies have shown that this method increases students' motivation when applied in learning environments (Adebayo & Olufunke, 2015; Akkılık, 2016; Astiti, Ibrahim, & Hariyono, 2020; Gernale, Duad, & Arañes, 2015; Kearney & Treagust, 2001; Widyanigrum, Bintari, & Rahayuningsih, 2018). Methods like POE and PDEODE, with their student-centered structure, not only support intrinsic motivation but also positively influence academic achievement. These strategies, particularly in enhancing critical thinking, problem-solving, and communication skills, increase student engagement in lessons and contribute to making the learning process more lasting. Astiti, Ibrahim, & Hariyono (2020) noted that laboratory activities conducted with the POE method positively altered students' academic motivation. Similarly, Akkılık (2016) found that learning activities using the POE method positively contributed to students' conceptual understanding and motivation. Yıldırım and Maşeroğlu (2016) also stated that the "Prediction" stage of the POE method increased students' motivation towards the lesson. Since PDEODE is an enriched version of the POE method with discussions, it parallels the POE method in terms of its application. The motivational benefits of the POE method in learning environments can also be attributed to the PDEODE.

The integration of PDEODE with visualization and interaction positively impacts students' learning outcomes and learning environment, boosts their motivation, enhances learning, fosters a deeper understanding, and increases students' self-confidence (Kolari & Savander-Ranne, 2004). Wulandari et al. (2017) suggest that the scoring/assessment and rewarding steps of the PDEODE method significantly contribute to creating a positive and motivating classroom atmosphere. This, in turn, enhances students' motivation, leading to greater success in their learning process. The rewards based on quiz results encourage students to compete responsibly within their groups, fostering a sense of cooperation among group members. As the spirit of competition grows, students are increasingly motivated to improve and surpass their peers, which drives them to refine their critical thinking skills. This demonstrates the strong relationship between the PDEODE method and student motivation. Additionally, PDEODE significantly improves students' communication skills across different academic abilities (Dipalaya, Susilo, & Corebima, 2016). While not specifically addressing academic intrinsic motivation, the Predict-Observe-Explain strategy, which is similar to PDEODE, has been found to motivate learners and enhance achievement in chemistry among secondary school students (Sreerekha, Arun, & Swapna, 2016). These studies collectively suggest that PDEODE is an effective instructional method that positively influences various cognitive and communicative skills in students, potentially contributing to increased academic motivation.

When students' opinions were examined in the study, they expressed that during the PDEODE activities, they felt positive emotions such as self-confidence, the joy of achieving something, and self-discipline, while also overcoming their fears of failure. In addition, during the discussion stages of the PDEODE activities, students reported that they were able to express their thoughts freely, and their academic motivation was positively influenced when their ideas were approved by their peers. In light of these student opinions, it is understood that laboratory activities conducted with the PDEODE method have a positive impact on academic intrinsic motivation. There are studies in the literature supporting this result (Chimmalee & Anupan, 2024; Karaduman & Uyulgan, 2021; Samsudin et al., 2021; Widyastuti et al., 2019; Wulandari et al., 2017). Wulandari et al. (2017) suggested that the decrease in social interaction during the discussion stages of the PDEODE method could be addressed through collaborative group work, and they found that such activities improved students' motivation and self-confidence. They also stated that academically motivated students' academic achievements would be positively affected. Widyastuti et al. (2019) reported that learning with the PDEODE method would lead to deeper and more lasting learning, improved learning abilities, and increased learning motivation, as well as enhanced self-confidence. Additionally, some studies have reported that students' academic intrinsic motivation reflects in their academic success (Uyulgan & Akkuzu, 2014; 2018).

The core features of the PDEODE model have been found to be highly effective in developing students' conceptual understanding, acquiring scientific process skills, and increasing their interest in laboratory work. Previous research also emphasizes the positive cognitive and sensory effects of laboratory experiences (Abrahams & Reiss, 2012; Hofstein & Mamlok-Naaman, 2007). This study shows that the addition of discussion components to the traditional POE model further enhances students' motivation. The discussion components allow students to better express their thoughts and defend their opinions, making the learning process more meaningful.

In addition, the findings of the study show that the PDEODE model leads to significant improvements in students' social acceptance, achievement needs, and expertise. This is consistent with previous research indicating that interactive and discussion-based learning environments, which support the constructivist approach, support students' learning motivation (Dipalaya & Corebima, 2016; Lathifa, 2018).

Self-regulation is defined as students' ability to effectively manage their own learning processes or tasks in line with predetermined goals. According to the literature, when supported by cloud-based technologies, the PDEODE method encourages students' engagement in lessons through more collaborative activities (Chimmalee & Anupan, 2024). During this process, students exchange ideas, develop awareness and reflection on their own thoughts, collaborate in small groups, and are encouraged to participate in discussions. Such interactive and collaborative learning environments may provide opportunities for students to exercise their autonomy. According to the Self-Determination Theory (SDT), fulfilment of the need for autonomy can significantly enhance intrinsic motivation, as it enables individuals to feel a sense of volition and control over their learning processes (Deci & Ryan, 1985). Although a direct relationship between the PDEODE method and Self-Determination Theory has not been clearly established in the literature, this method has been reported to positively influence students' self-regulation skills (Chimmalee & Anupan, 2024). Elements such as students' evaluation of their own and their peers' work, and monitoring their level of understanding, support the development of self-regulation. Therefore, even though a direct link has not been identified, it can be suggested that the interactive and collaborative nature of the PDEODE method contributes to the development of self-regulation skills and thereby indirectly supports components associated with self-determination, such as autonomy. In this way, the PDEODE method may enhance students' motivation and engagement in learning processes by contributing to the fulfilment of one of the core needs emphasized in Self-Determination Theory.

In this context, the application of the PDEODE model in science education is considered an effective method for both increasing students' academic success and sustaining their learning motivation. Future research on the application of this model in different subjects and learning levels may contribute to a better understanding of the model's general applicability.

SUGGESTIONS

Based on the findings and limitations of this study, several recommendations are proposed to enhance academic intrinsic motivation and improve the effectiveness of the PDEODE method in science education.

- Academic intrinsic motivation is a continuous process; activities aimed at boosting motivation should not be restricted to specific time frames. Motivation levels should be continuously monitored throughout the teaching process and adjusted based on students' progress.
- This study demonstrated short-term motivation increases with a six-week implementation of the activities. Future research could explore the long-term effects by applying these teaching methods over extended periods. Analysing long-term changes in student motivation could promote lasting learning and achievement.
- Although the findings of this study provide valuable insights into the impact of the PDEODE method on students' academic intrinsic motivation, the relatively small sample size (n=38) limits the generalizability of the results. Therefore, caution should be exercised when extending the conclusions to broader populations, and future research with larger and more diverse samples is recommended to validate and expand upon these findings.
- To enhance the effectiveness of the PDEODE method, activities should be designed with real-life applications to increase students' engagement and curiosity.
- PDEODE activities should encourage collaboration and peer discussion to maximize the benefits of the discuss-explain stages.
- Instructors should provide timely feedback during and after PDEODE activities to reinforce students' understanding and motivation.
- The method should be integrated into various science subjects, not just chemistry, to evaluate its broader impact on scientific thinking and problem-solving skills.

Ethical Statement

This study was not supported by any institution. The authors declare that there is no conflict of interest. This study was conducted in accordance with ethical standards, and ethical approval was obtained from the Legal Consultancy of the Rectorate of Dokuz Eylül University, dated 30.03.2021, with the reference number E-87347630-640.99-36366.

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GENİŞLETİLMİŞ ÖZET

Bu araştırma, kimya eğitiminde öğrencilerin akademik içsel motivasyonunu artırmak amacıyla geliştirilen tartışmalarla zenginleştirilmiş TGA (TaTGA) yöntemine dayalı kimya laboratuvar etkinliklerinin etkisini incelemektedir. Tahmin-Gözlem-Açıklama (TGA) yönteminin genişletilmiş hali olan bu yöntem, öğrencilerin gözlemlenen olayların sonuçlarını daha derinlemesine tartışmalarına olanak tanıyarak motivasyonlarını ve merak duygularını daha fazla desteklemeyi amaçlamaktadır. Uygulamalı etkinlikler, laboratuvar deneyleri ve gerçek dünya problemlerinin çözümüne yönelik görevleri bütünleştirerek, TaTGA yöntemi anlamlı ve uyarıcı bir öğrenme ortamı oluşturmakta; bu da öğrencilerin içsel motivasyonlarını ve fen bilimlerine olan ilgilerini artırmaktadır. Bu yöntemin öğrencilerin içsel motivasyonlarını ve bilimsel içeriklerle etkileşimlerini nasıl etkilediğini araştırarak, çalışma; yenilikçi ve etkili fen öğretim uygulamalarının geliştirilmesine anlamlı bir katkı sağlamayı, modern eğitim ve pedagojik eğilimlerle uyumlu biçimde fen eğitiminin niteliğini kapsamlı bir şekilde artırmayı hedeflemektedir.

Araştırmanın problemi, fen eğitimi ortamlarında öğrencilerin içsel motivasyonlarının nasıl artırılabileceğine dair etkin bir öğretim yaklaşımına duyulan ihtiyaçtan kaynaklanmaktadır. Çalışmanın amacı, TaTGA yönteminin fen bilgisi öğretmen adaylarının akademik içsel motivasyonları üzerindeki etkisini nicel ve nitel verilerle ortaya koymaktır. TaTGA modeli, klasik TGA yaklaşımının tartışma adımlarıyla geliştirilmiş bir versiyonu olup, öğrencilerin tahmin yapma, gözlem yapma ve açıklama becerilerini, karşılıklı fikir alışverişi ile daha derinlemesine geliştirmeyi amaçlamaktadır.

Araştırmada Kimya 2 dersinin uygulama dersleri kapsamında gerçekleştirilen kimya laboratuvarı deneylerinde öğrenilmesi hedeflenen bilgilerin doğru ve etkili biçimde aktarılabilmesi amacıyla, nedensel ilişkileri araştırmaya ve deneysel ya da anket yöntemleriyle yeterince açıklanamayan karmaşık süreçleri derinlemesine incelemeye uygun olan açıklayıcı durum çalışması deseni tercih edilmiştir. Araştırma, Türkiye'nin batısında yer alan bir devlet üniversitesinin Fen bilgisi öğretmenliği programına kayıtlı birinci sınıfta okuyan 38 öğrenciyle yürütülmüştür. Çalışmada amaçlı örnekleme yöntemi kullanılmıştır. Katılımcıların tamamı TaTGA yöntemi ile ilk kez tanışmış ve ilgili deneysel konuları ilk kez bu çalışmada işlemişlerdir. Araştırma süreci toplam dokuz hafta sürmüş, ilk hafta ön test uygulanmış ve TaTGA yöntemi tanıtılmış, sonraki altı hafta boyunca her hafta bir deneysel etkinlik gerçekleştirilmiş, sekizinci haftada son test uygulanmış ve dokuzuncu haftada çalışma sürecine yönelik öğrenci görüşleri toplanmıştır. Covid-19

pandemisi nedeniyle etkinlikler bir çevrim içi öğretim platformu üzerinden gerçekleştirilmiştir. Araştırma kapsamındaki kimya laboratuvar deneyleri araştırmacılar tarafından önceden video kaydı oluşturularak hazırlanmış, canlı derslerde öğrenciler bu videoları izleyerek TaTGA basamaklarına uygun olarak etkinlikleri gerçekleştirmişlerdir.

Veri toplama araçları olarak Uyulgan ve Akkuzu (2014) tarafından geliştirilmiş olan Akademik İçsel Motivasyon Ölçeği (AİM) ve yapılandırılmış görüşme formu kullanılmıştır. AİM ölçeği dört alt boyuttan oluşmaktadır. Bunlar; başarı ihtiyacı, uzmanlık, sosyal kabul ve başarısızlık korkusudur. Ölçek 1'den 7'ye kadar derecelendirilmiş 23 maddeden oluşmaktadır. Ölçekten elde edilen ön test ve son test verileri için normal dağılım varsayımı test edilmiş ve verilerin parametrik testlere uygun olduğu belirlenmiştir. Veriler SPSS 21 programında eşleştirilmiş örneklem t-testi ile analiz edilmiştir. Ayrıca, görüşmelerden elde edilen nitel veriler betimsel analiz yoluyla değerlendirilmiş ve öğrencilerin yanıtları tema ve alt temalar halinde sınıflandırılmıştır.

Araştırma bulguları, TaTGA yönteminin öğrencilerin akademik içsel motivasyonunu anlamlı düzeyde artırdığını göstermektedir. Öğrencilerin ölçekten aldıkları ön test ve son test puan ortalamaları arasında istatistiksel olarak anlamlı farklar bulunmuştur. AİM ölçeğinin başarı ihtiyacı, uzmanlık ve sosyal kabul boyutlarından alınan puanlarda artışlar saptanmıştır. Özellikle başarı ihtiyacı boyutunda öğrenciler, görev tamamlama ve daha iyi performans gösterme yönünde kendilerini daha motive hissettiklerini belirtmişlerdir. Uzmanlık boyutunda, öğrenciler kendi bilgi ve yeteneklerini sınama fırsatı bulduklarını, bu sayede bireysel olarak daha fazla çaba gösterme eğiliminde olduklarını ifade etmişlerdir. Sosyal kabul boyutunda ise, öğrenciler fikirlerinin grup içinde onaylanmasının kendilerini motive ettiğini ve özgüvenlerini artırdığını belirtmişlerdir. Başarısızlık korkusu boyutunda her ne kadar anlamlı bir farklılık çıkmasa da nitel bulgular öğrencilerin bu korkularının azaldığını ortaya koymuştur.

Yapılandırılmış görüşme formundan elde edilen nitel veriler, nicel sonuçları destekler niteliktedir. Öğrenciler, TaTGA yöntemiyle yapılan etkinliklerin başarı hissi yarattığını, hatalarından çıkardıkları sonuçların öğrenmelerine olanak sağladığını ve fikirlerini özgürce ifade edebildikleri bir ortam sunduğunu belirtmişlerdir. Öğrenciler aynı zamanda, deneysel süreçlere katılımın bilgi düzeylerini artırdığını, kavramsal anlamalarını güçlendirdiğini ve bilimsel süreç becerilerini geliştirdiğini vurgulamışlardır. Görüşme sonuçları tartışma aşamalarının özellikle düşünsel derinliği artırdığını ve öğrencilerin bilimsel kavramlarla daha güçlü bağ kurmasını sağladığını göstermiştir.

Araştırma sonuçları, TaTGA yönteminin akademik içsel motivasyonu artırıcı etkisi olduğunu göstermektedir. Literatürdeki benzer çalışmalara paralel olarak, bu yöntemin öğrenci merkezli ve etkileşimli yapısı sayesinde hem bilişsel hem de duyuşsal çıktılar üzerinde olumlu etkiler yarattığı sonucuna varılmıştır. Ayrıca, TaTGA modelinin özerklik, yeterlik ve ilişkililik gibi öz belirleme kuramının temel bileşenleriyle örtüştüğü ve bu yönüyle öğrencilerin öz düzenleme becerilerini desteklediği ortaya çıkmıştır. Öğrencilerin kendi öğrenme süreçleri üzerinde kontrol hissi yaşamaları ve grup içinde fikirlerini paylaşabilmeleri, öğrenme sürecine olan katılımlarını artırarak içsel motivasyonlarını pekiştirmiştir.

Araştırmanın sınırlılıkları, deneylerin fiziksel olarak uygulanamaması ve çevrim içi ortama bağlı olarak etkileşimin sınırlı düzeyde gerçekleşebilmesidir. Ancak, öğrencilerin deneysel videolarla yönlendirilerek sürece aktif katılımlarının sağlanması, araştırma amacının gerçekleştirilmesine engel teşkil etmemiştir.

Sonuç olarak, bu araştırma TaTGA yönteminin kimya öğretiminde öğrencilerin akademik içsel motivasyonlarını artırmak için etkili bir strateji olduğunu göstermektedir. Gelecekte farklı derslerde ve öğrenme düzeylerinde yapılacak çalışmalarla bu yöntemin geçerliliği ve uygulama alanları genişletilebilir. Ayrıca, uzun vadeli etkilerin inceleneceği çalışmalara ihtiyaç duyulmaktadır. TaTGA tabanlı etkinliklerin gerçek yaşamla ilişkilendirilerek, öğrencilerin bilimsel düşünme, problem çözme ve iletişim becerilerini geliştirmede etkili olabileceği sonucuna varılmıştır. Bu yönüyle çalışma, fen eğitimi alanında öğrenci merkezli ve motivasyonu destekleyici öğretim stratejileri geliştirilmesine katkı sağlamaktadır.