Evaluation of Self-efficacy Perceptions and Attitudes towards Augmented Reality of High School Teachers Teaching Chemistry Course

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***Abstract*—This study aimed to evaluate high school chemistry teachers' self-efficacy perceptions and attitudes toward augmented reality using a systematic structural approach. This research was designed as a mixed-methods study. The study group consisted of 360 chemistry teachers. Data were collected through the self-efficacy scale for teaching in the laboratory, the Teachers' Augmented Reality Competencies Scale (TARC), and a semi-structured interview form developed by the researchers. Quantitative data were analyzed using a statistical program, while descriptive analysis was used to examine the qualitative data. The findings revealed that teachers generally reported high self-efficacy levels for teaching in the laboratory, as well as high scores on the augmented reality competency scale. The research findings show that chemistry teachers' self-efficacy levels for teaching in the Laboratory were generally high. However, correlation analysis showed no statistically significant relationship between self-efficacy levels and augmented reality competencies. Based on these results, recommendations were proposed in alignment with the principles and components of the systematic structural approach.**

***Keywords*—chemistry teachers, self-efficacy, augmented reality, systematic structural approach, mixed method**

I. Introduction

The systemic structural method has notable benefits in tackling complex problems, especially due to its comprehensiveness, interconnectivity, and adaptability. This methodology enables a comprehensive analysis of issues, encompassing the complex interrelations and dynamics inside systems, which is crucial in today's convoluted world. Mohaghegh and Furlan [1] assert that systematic problem-solving facilitates a profound comprehension of the antecedents affecting difficulties, hence promoting a holistic solution framework.

Interconnectedness constitutes another essential characteristic of the systemic structural approach. Edson and Klein [2] emphasize that this method highlights the significance of comprehending the interactions among diverse components within a broader framework, thereby allowing academics and practitioners to identify dependencies and possible areas of effect. This perspective diverges from conventional methodologies that tend to compartmentalize issues, resulting in inadequate analysis and inferior solutions.

The flexibility of the systemic structural approach is essential for addressing emerging difficulties. Kasser [3] emphasizes that systems engineering, as a holistic and methodical approach, adapts to evolving circumstances and increasing complexities, guaranteeing that solutions stay pertinent and efficient. Zlatanović [4] similarly emphasizes the effectiveness of a multi-methodological approach in addressing complex problem-solving situations within companies. The systemic structural approach excels in offering extensive, interrelated, and adaptive frameworks for tackling complicated situations, rendering it superior to traditional problem-solving methods.

Self-efficacy, characterized as an individual's conviction in their capacity to achieve success in particular contexts, significantly influences perceptions of nascent technologies such as Augmented Reality (AR). The link between self-efficacy and perceptions of nascent technologies is especially relevant in educational contexts, where the incorporation of AR could improve learning experiences. Ripsam and Nerdel [5] investigated educators' attitudes and self-efficacy toward the implementation of augmented reality in chemistry education, revealing that individuals with elevated self-efficacy were more inclined to embrace augmented reality approaches. This indicates that cultivating a sense of competence among educators is essential for the effective incorporation of AR into courses.

Berdousis [6] revealed that teachers with extensive technological backgrounds exhibit higher self-efficacy. Simultaneously, Yulian, Yuniarti, and Sirat [7] examined the relationship among self-efficacy, attitude, and self-regulated learning in English as a Foreign Language (EFL) learners. Their findings demonstrate that self-efficacy favorably affected learners' attitudes towards utilizing AR, thus augmenting their motivation and involvement in reading activities. This underscores the psychological ramifications of self-efficacy, demonstrating its ability to enhance learners' engagement with instructional tools.

Self-efficacy affects not only engagement but also motivation. Kari [8] observed that augmented reality can enhance intrinsic motivation in pupils, particularly when they have a robust feeling of self-efficacy. As students attain success in AR environments, their views of personal efficacy increase, establishing a circle of accomplishment and enthusiasm.

O'Connor and Mahony [9] further substantiated this thesis by examining the impact of augmented reality on student academic self-efficacy in higher education. Students who were satisfied with AR technologies demonstrated increased self-efficacy, resulting in favorable attitudes towards academic obstacles. Yulian, Yuniarti, and Lee [10] emphasized the importance of technological adoption, observing that enhanced self-efficacy in AR usage among students fostered favorable changes in their views toward learning English. Gbadegesin *et al.* [11] indicated that Virtual

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Reality (VR) and Augmented Reality (AR) technology present promising opportunities for enhancing physical education through increased motivation and the learning of motor skills.

Hidayati *et al.* [12] demonstrated that the use of augmented reality within an authentic learning framework markedly enhances students' comprehension and participation in science education. Aldeeb *et al.* [13] substantiated these findings by illustrating that mobile AR treatments significantly enhanced students' academic performance, self-efficacy, and motivation. Self-efficacy increases users' comfort with AR technology, making it a vital element in technological adoption and educational innovation, hence underscoring the need to comprehend this construct within the realm of AR applications.

Augmented reality applications in education, especially within Chemistry, provide a systematic structural framework that dramatically impacts students' self-efficacy, attitudes, and perceptions. These variables subsequently impact academic achievement, indicating a complicated interaction that warrants more investigation. Self-efficacy, characterized as an individual's conviction in their capacity to achieve success in a specific endeavor, significantly influences educational achievements. O'Connor and Mahony [9] assert that augmented reality technology can enhance academic self-efficacy by offering immersive experiences that more profoundly engage students in the learning process. The implementation of augmented reality fosters an interactive environment that enables students to perceive intricate chemical reactions and processes, hence enhancing their confidence in their abilities [13]. Similarly, Lin *et al.* [14] noted that students' cognitive load in AR-assisted Science learning is closely correlated with their self-efficacy and ensuing behavioral patterns.

Furthermore, educators' attitudes towards augmented reality can profoundly influence students' views and levels of involvement. Ripsam and Nerdel [5] discovered that educators' self-efficacy regarding the utilization of AR affects their integration of these tools into their teaching practices. Favorable teacher attitudes towards technological advancements can foster a supportive learning environment that improves students' perceptions of augmented reality as an effective educational tool. Conversely, adverse views may lead to resistance against these technological advancements, thereby undermining students' interest and self-efficacy.

Perceptions of augmented reality technologies significantly influence the educational environment. When students recognize augmented reality as advantageous to their education, they are more inclined to interact with the content and demonstrate favorable attitudes towards their academic pursuits. Elford *et al.* [15] assert that, in Chemistry teaching, AR applications help elucidate intricate topics, enabling students to develop more positive attitudes toward the discipline. Positive impressions can lead to enhanced academic performance, as students are more inclined to dedicate time and effort to subjects they deem accessible and enjoyable.

The systematic structural method of AR is corroborated by studies demonstrating its effectiveness in improving motivation and learning results. Aldeeb *et al.* [13] assert that mobile augmented reality enhances students' academic performance, their motivation, and self-efficacy, indicating that the incorporation of organized augmented reality experiences in Chemistry lectures can be revolutionary. Indayati, Rahayu, and Karinsa [16] examine the synergy of augmented reality and alternate reality games in enhancing self-efficacy, illustrating a wider application of systematic strategies that go beyond conventional ways.

Considering the findings presented so far, the following questions arise: Do systematic structured methods for integrating augmented reality into chemistry education create a conducive environment for developing students' self-efficacy, changing their attitudes, and transforming their perceptions? By focusing on improving teacher attitudes and ensuring the comprehensive integration of augmented reality technologies, can educational stakeholders provide more effective learning environments that meet the needs of contemporary students? Most importantly, what are the self-efficacy perceptions and attitudes of high school teachers who teach chemistry using a systematic structured approach towards augmented reality? The lack of comprehensive research on this topic to date is seen as one of the research gaps in the field. Therefore, conducting a scientific study on this subject is considered a necessity.

A. *Purpose of the Study*

The purpose of this study was to evaluate self-efficacy perceptions and attitudes towards augmented reality of high school teachers teaching chemistry course according to a systematic structural approach. To achieve this goal, the following questions were addressed:

Numbered lists can be added as follows:

(1) What is the level of self-efficacy perception of chemistry teachers?
(2) What is the level of augmented reality competencies of teachers?
(3) What is the relationship between chemistry teachers' self-efficacy perceptions and their augmented reality competencies?
(4) What are teachers' views on self-efficacy and augmented reality competencies, according to the systematic approach?

II. Materials and Methods

This section of the research includes information about the selected method in accordance with the purpose of the research. Also, the study group, the data collection tool, the data evaluation technique, and the ethical processes are included in this section.

A. *Research Method*

This research was designed as mixed-method research. Mixed-method research is defined as combining the views of researchers who adopt only one research paradigm, researchers who adopt a situational research paradigm, and researchers who adopt a utilitarian research paradigm in a study. In this method, quantitative and qualitative methods are used together. During the presentation phase of the data collected in both ways, the findings obtained from both data sets are blended, and the advantages of presenting the data collected in two separate ways as a whole are utilized [17]. In this study, a mixed-method approach was preferred in order to evaluate the self-efficacy perceptions and attitudes of high school chemistry teachers regarding augmented reality in a multifaceted and in-depth manner according to the systematic structural approach.

1) Integration of quantitative and qualitative findings

In this mixed-methods study, integration was achieved at the interpretation stage using a convergent explanatory strategy. Quantitative findings obtained from the Self-Efficacy Scale for Teaching in the Laboratory (SEPTL) and Teachers' Augmented Reality Competencies scale (TARC) scales were first analyzed to determine teachers' levels of self-efficacy and augmented reality competencies. Subsequently, qualitative data derived from semi-structured interviews were used to explain, support, and contextualize these quantitative results. Teachers' interview responses were interpreted in relation to their scale scores, allowing qualitative insights to clarify why certain competencies appeared high, while no statistically significant relationship emerged between laboratory self-efficacy and augmented reality competencies. This integrative approach enhanced the depth and clarity of the findings within the systematic structural framework.

B. Participants

Kazakhstan is a Central Asian nation characterized by a fusion of nomadic heritage and contemporary influences. It was significant in the history of the Silk Road, linking it with diverse civilizations. Ethnic diversity holds significance in Kazakhstan, where Kazakhs and Russians represent the predominant groups. Traditional customs, including yurt habitation, equestrianism, and eagle hunting, hold substantial significance. Music and instruments such as the dombra constitute an integral aspect of their cultural history. Since attaining independence in 1991, Kazakhstan has implemented a series of reforms aimed at synchronizing higher education with European standards. The educational system comprises primary, secondary, and high school levels, with a trilingual education policy that includes Kazakh, Russian, and English. The Abai Kazakh National Pedagogical University and Nazarbayev University are prominent institutes in teacher training and educational studies. Recent digital initiatives, including vocational training and online learning platforms, are significant. Challenges, including disparities between rural and urban areas and the need for teacher training, persist.

It was estimated that there were a total of 1950 chemistry teachers in the Almaty region of Kazakhstan at the time of conducting this research. Reaching all of them was a very difficult process. Therefore, a random sampling method was used in the present study. This study sample included 360 chemistry teachers selected randomly. The teachers were teaching chemistry course in various high schools in Almaty city of Kazakhstan, in the 2024–2025 academic year. One hundred and sixty-two (45%) of the teachers participating in the study were female, and 198 (55%) were male. The sample group of the study was determined by the convenience sampling method. This sampling is a sampling made on individuals who are easy to reach, available, and willing to participate in the study (volunteers) [18]. Thus, 360 teachers were included in the sample group.

C. Data Collection Tools

Research data were collected using the SEPTL, the TARC and the semi-structured interview form for chemistry teachers developed by the researchers.

The SEPTL was developed by Turan-Oluk *et al*. [19]. The SEPTL scale contains three factors and 29 items. Factor 1 (conducting experiments) contains 13 items and explains 28.372% of the total variance. Factor 2 (using technology in the laboratory) contains nine items and explains 16.654% of the total variance. Factor 3 (laboratory safety) contains seven items and accounts for 14.023% of the total variance. The entire scale accounts for 59.049% of the variance. Cronbach's α coefficient was found to be 0.957 for the whole scale, 0.952 for Factor 1, 0.878 for Factor 2, and 0.875 for Factor 3.

This scale was developed in Turkey. The scale was adapted from Turkish to Kazakh by a forward-backward translation process, and expert evaluations were conducted for linguistic equivalence. A pilot study was performed with an independent sample of 112 chemistry educators. The scale's overall reliability coefficient was determined to be Cronbach's alpha = 0.862. The values for the sub-dimensions were computed as follows: "conducting experiments" 0.834, "using technology in the labs" 0.891, and "lab safety" 0.862. The results indicated that the scale is valid and reliable within the Kazakh setting.

The TARC was developed by Nikou *et al.* [20]. The scale consists of 11 items and 4 factors. Design, Develop and Modify (DDM) factor's Cronbach α coefficient was 0.929, Pedagogy, Teaching, Assessment and Feedback (PTAF) factor's Cronbach α coefficient was 0.944, Search, Evaluate and Organize (SEO) factor's Cronbach α coefficient was 0.962, and Ethics and Safety (ES) factor's Cronbach α coefficient was 0.963. The fact that this value was greater than 0.70 for the overall scale reveals that it was a reliable scale.

The scale was adapted from English to Kazakh using a forward-backward translation method, and expert assessments were performed for linguistic equivalence analysis. A pilot study was conducted using a specific sample of 112 chemistry educators. The overall reliability coefficient of the scale was established as Cronbach's alpha = 0.915. The values for the sub-dimensions were calculated as follows: "DDM" 0.914, "PTAF" 0.931, "SEO" 0.892, and "ES" 0.924. The findings demonstrated that the scale is both valid and reliable in the Kazakh context.

1) Chemistry teachers semi-structured interview form

The semi-structured interview form created by the researchers was prepared to evaluate the opinions of chemistry teachers when considering their self-efficacy and augmented reality competence results according to the Systematic structural approach. There were 3 open-ended questions in the form. The purpose of creating these open-ended questions was to evaluate teachers' opinions on the results after the scale application results were shared with them. The open-ended questions created were presented to a language expert for his/her opinion, and he/she was asked to evaluate the clarity of the questions. The questions were revised and turned into a form in line with the opinions of the language expert. The semi-structured chemistry teachers' interview form was applied to 2 teachers who found the questions clear and understandable. The 2 teachers who participated in this evaluation section of the study were excluded from the sample group of the study. The semi-structured interview form was applied face-to-face to 40 teachers randomly selected from the sample group of the study. The questions in the semi-structured chemistry teachers' interview form are given below.

(1) In line with the systematic structural approach, how would you explain your level of self-efficacy for laboratory teaching?
(2) In line with the systematic structural approach, how do you evaluate your level of competence in augmented reality technologies?
(3) In line with the systematic structural approach, what is your opinion on the relationship between self-efficacy and augmented reality competencies?

The first question aimed to reveal the teacher's subjective assessment of their own pedagogical and technical competence in the laboratory teaching process. It also reflected the effect of the systematic structural approach on individual perception. The second question aimed to determine the teacher's self-perception of their cognitive, technical, and pedagogical competence regarding augmented reality technologies within the systematic structural framework. The third question aimed to explain the relationship that the teachers perceive between the two competence structures. In other words, the respondent indicates whether these competencies are perceived as complementary, independent, or interfering with one another. The semi-structured interview form that was created aimed to reveal how the quantitative findings obtained from the SEPTL (self-efficacy) and TARC (augmented reality competence) scales complement qualitative data.

D. Data Collection Process

The quantitative data of the study were collected by applying the selected scale to chemistry teachers face-to-face, in the classroom, and collectively. The 2 scales used to collect the quantitative data of the study were applied to the teachers simultaneously. The qualitative data of the study were collected through face-to-face interviews. The results obtained from the evaluations made as a result of the collection of quantitative data were shared with the 40 selected teachers, and a semi-structured interview form was applied to the chemistry teachers in this direction. The collection of all research data was carried out gradually and lasted approximately 7 weeks.

E. Compliance with Ethics

A research ethics consent form was created for all experts and teacher candidates who contributed to the research during the application phase of the data collection tools. The consent form stated that the purpose of the research, personal data would be kept confidential and would not be used in any other research. Participants who were informed through the consent form signed a voluntary participation statement, declaring that participation in the research was undertaken willingly. In addition, data collection processes at all stages of the research were carried out with the knowledge and approval of the institutions where the data collection processes were carried out. In the writing phase of the research, research ethics were followed.

F. Data Analysis

The quantitative data of the study were analyzed with the SPSS 25.0 statistics program. In the data analysis process, the Kolmogorov-Smirnov test, which is the initial criterion of parametric statistical techniques, was applied. As a result of the analysis, it was determined that the data sets obtained from both scales showed normal distribution and thus, parametric tests were applied. Bivariate correlation was used as a parametric test. The significance level was determined as 0.05. A descriptive analysis method was used in the analysis of the quantitative data. Marshall [21] stated that the purpose of descriptive analysis is to organize and interpret the data obtained through observation or interviews and present them to the reader. In this context, chemistry teachers' opinions were evaluated using the descriptive analysis method in relation to their self-efficacy and augmented reality competencies within the systematic structural approach, and the results were presented in a table.

Qualitative data were analyzed using descriptive analysis supported by a systematic coding process. Interview transcripts were read repeatedly, and meaningful statements were identified and coded independently by the researchers. Similar codes were grouped into categories reflecting teachers' perceptions of self-efficacy, augmented reality competence, and their perceived relationship. These categories were then compared with quantitative findings from the SEPTL and TARC scales to ensure consistency and integration. Frequencies of categories were calculated and presented in tables to strengthen the connection between qualitative interpretations and quantitative results.

III. Results

Table 1 shows the SEPTL scores of the chemistry teachers who participated in the study.

When the descriptive statistics regarding the SEPTL in Table 1 are examined, it is seen that the total scores of the participants ranged from 29 to 145, and the arithmetic mean was 103.55 (SD = 20.29). The scale contained 29 items in total and was evaluated with a 5-point Likert-type scoring (1 = Strongly Disagree, 5 = Strongly Agree). In this context, the total score ranged from 29 to 145, and the mean obtained showed that the participants' self-efficacy perceptions for teaching in a laboratory environment were at a high level.

When the analyses related to the sub-dimensions of the scale were examined, the scores related to the "Conducting Experiments (CE)" sub-dimension ranged from 13 to 65, and the average score was calculated as 50.67 (SD = 7.04). This result indicated that the participants' self-efficacy levels regarding the planning and implementation of laboratory experiments were high. In the "Using Technology in the Lab (UTL)" sub-dimension, the minimum and maximum scores ranged from 9 to 45, and the average was found to be 30.20 (SD = 8.95). This value reveals that the self-efficacy perception regarding technology integration was at a medium-high level. In the "Lab Safety (LS)" sub-dimension, the scores ranged from 7 to 35, and the average value was determined as 22.66 (SD = 7.78). This indicates that the teacher candidates also had a high level of self-efficacy perception regarding laboratory safety.

Table 1. Chemistry teachers' Self-Efficacy Scale for Laboratory Teaching (SEPTL) scores

Scales	N	Min	Max	*M*	SD
SEPTL Total	360	29.00	145.00	1035,500	20.28674
Conducting experiments	360	13.00	65.00	506,722	7.04014
Using technology in the lab	360	9.00	45.00	302,083	8.95476
Lab safety	360	7.00	35.00	226,694	7.78322

N = Sample size; Min = Minimum score; Max = Maximum score; M = Mean; SD = Standard Deviation

Table 2. Chemistry teachers' scores on the Teachers' Augmented Reality Competencies scale (TARC)

Scales	N	Min	Max	*M*	SD
TARC Total	360	15.00	55.00	423,639	8.72791
DDM	360	3.00	15.00	110,444	3.23253
PTAF	360	3.00	15.00	116,083	3.03268
SEO	360	3.00	15.00	117,611	3.14703
ES	360	2.00	10.00	79,500	2.12106

N = Sample size; Min = Minimum score; Max = Maximum score; M = Mean; SD = Standard Deviation

The fact that the mean scores in the context of all sub-dimensions in the scale are above the theoretical average (3.00 per item) shows that the participants' self-efficacy perceptions in the context of laboratory teaching are generally at a positive level. However, the relatively low standard deviation values suggest that there were no major differences between the participants' self-efficacy levels and that the response distribution has a homogeneous structure.

Table 2 shows the Teachers' Augmented Reality Competence scale (TARC) scores of chemistry teachers.

When the descriptive statistics of the Teachers' Augmented Reality Competency (TARC) scale, which aimed to measure teachers' competence levels towards augmented reality technologies, are examined in Table 2, it is observed that the total scale scores vary between 15 and 55, and the average score is 42.36 (SD = 8.72). The scale was created with a 5-point Likert-type rating based on 11 items, and the theoretical maximum score is 55. In this context, the average score obtained by the participants from the overall scale indicated that their general competence perception towards augmented reality technologies was at a high level.

In the first sub-dimension of the scale, Design, Develop, and Modify (DDM), the scores range from 3 to 15, with an average value of 11.04 (SD = 3.23). This factor represents teachers' skills in designing and adapting augmented reality content. The average score indicated a sufficient and positive perception in this area as well.

The average for the Pedagogy, Teaching, Assessment, and Feedback (PTAF) factor was determined as 11.60 (SD = 3.03), with a minimum of 3 and a maximum of 15. This finding indicated that the competence levels for integrating augmented reality technology into pedagogical processes and using it in teaching, evaluation, and feedback processes were high.

The mean score for the Search, Evaluate, and Organize (SEO) factor was 11.76 (SD = 3.14), indicating that teachers have a positive perception of competence in researching, evaluating, and organizing augmented reality content.

Finally, in the Ethics and Safety (ES) sub-dimension, the scores ranged from 2 to 10, with an average of 7.95 (SD = 2.12). This value revealed that teachers' awareness of ethical principles and safety in the use of augmented reality technology was also strong.

The fact that the means for all sub-dimensions and the overall scale were close to the upper half of the score ranges indicated that teachers' self-efficacy levels for augmented reality were high. In addition, low standard deviation values indicate that the perceptions of these competencies were homogeneous among the participants.

Table 3 presents the participating chemistry teachers' perceived self-qualifications regarding augmented reality capabilities in laboratory teaching. The relationship between the variables was not evaluated.

Table 3. Chemistry teachers perceived self-efficacy in laboratory teaching with increased reality VR capabilities and the relationships among these variables

SEPTL Total	CE	UTL	LS	TARC Total	DDM	PTAF	SEO	SPOUSE
1								
0.693 **	1							
0.924 **	0.418 **	1						
0.917 **	0.420 **	0.879 **	1					
−0.043	0.005	−0.052	−0.057	1				
0.033	0.078	0.016	−0.004	0.716 **				
−0.043	0.030	−0.063	−0.066	0.778 **	0.456 **	1		
−0.082	−0.070	−0.080	−0.058	0.805 **	0.332 **	0.464 **	1	
−0.044	−0.038	−0.031	−0.046	0.718 **	0.278 **	0.387 **	0.659 **	1

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3 presents the Pearson correlation coefficients for the relationships between chemistry teachers' Self-Efficacy Levels for Teaching in the Laboratory (SEPTL) and Their Augmented Reality Competencies (TARC). No statistically significant relationship was found between the total scores of the SEPTL and TARC scales ($r = –0.043$, $p > 0.05$). This result shows that teachers' self-efficacy perceptions regarding laboratory teaching are independent of their competencies regarding augmented reality technologies.

In the analyses made at the sub-dimension level, it was determined that the Experiment Conducting (CE), Use of Technology in Laboratory (UTL), and Laboratory Safety (LS) sub-dimensions of SEPTL did not show a statistically significant relationship with the Design, Develop and Modify (DDM), Pedagogy, Teaching, Assessment and Feedback (PTAF), Search, Evaluate and Organize (SEO), and Ethics and Safety (ES) sub-dimensions of TARC. The correlation coefficients were quite low ($r = −0.080$ to 0.078), and all p values were above 0.05. This situation indicates that teachers' perceptions of competence in experimental and technological processes in the laboratory do not overlap with their competencies regarding digital technologies such as augmented reality.

On the other hand, high-level and statistically significant correlations were observed among the sub-dimensions of the TARC scale. Strong relationships were found between the

TARC total score and the DDM ($r = 0.716$, $p < 0.01$), PTAF ($r = 0.778$, $p < 0.01$), SEO ($r = 0.805$, $p < 0.01$), and ES ($r = 0.718$, $p < 0.01$) sub-dimensions. In addition, all correlations between the sub-dimensions were positive, medium to high level, and significant. These findings show that augmented reality competencies have a holistic and consistent structure. In general, while teachers' augmented reality competencies exhibit a structured and high internal consistency structure, it is understood that these competencies are not related to their laboratory teaching self-efficacy perceptions.

Table 4 evaluates the responses of chemistry teachers to the question "How would you explain your level of self-efficacy for laboratory teaching in line with the systematic structural approach?"

Table 4. In line with the systematic structural approach, self-efficacy level for laboratory teaching

Category	F	%
High perception of self-efficacy	21	52.5
Moderate level of self-efficacy perception	10	25
Low perception of self-efficacy	6	15
Undecided / Not Clear	3	7.5
Total	40	100

Table 4 shows the descriptive analysis findings regarding the self-efficacy levels of chemistry teachers towards laboratory teaching in line with the systematic structural approach. Open-ended responses were analyzed through descriptive coding, and emerging themes were systematically aligned with the quantitative dimensions of the SEPTL and TARC scales. 52.5% of the participants stated their self-efficacy levels as high, 25% as medium, and 15% as low. In addition, 7.5% of the teachers did not express a clear opinion regarding their level of efficacy. The findings show that the majority of the participants evaluated their self-efficacy levels as high or medium.

Table 5 evaluates the responses of chemistry teachers to the question "How do you evaluate your level of competence in augmented reality technologies in line with the systematic structural approach?"

Table 5. In line with the systematic structural approach, level of competence in augmented reality technologies

Category	F	%
High perception of augmented reality technologies	20	50
Perception of mid-level augmented reality technologies	9	22.5
Low perception of augmented reality technologies	7	17.5
Undecided / Not Clear	4	10
Total	40	100

Table 5 presents the descriptive analysis findings regarding the competence levels of chemistry teachers towards augmented reality technologies in line with the systematic structural approach. 50% of the participants evaluated their competence level as high, 22.5% as medium level, and 17.5% as low level. 10% did not express a clear opinion regarding their competence level. The findings show that half of the teachers perceived augmented reality competence positively; however, a significant proportion thought that they had limited competence in this regard.

Table 6 evaluates the responses of chemistry teachers to the question "What is your opinion on the relationship between self-efficacy and augmented reality competencies in line with the systematic structural approach?"

Table 6. In line with the systematic structural approach, the relationship between self-efficacy and augmented reality

Category	F	%
Teachers who stated that there is a relationship, but it needs to be supported by education	12	30
Teachers who stated that they were not related	11	27.5
Teachers who think that there is a relationship, but that it will become stronger as technological competence develops	6	15
Teachers who are undecided about the relationship in line with the systematic structural approach	6	15
Teachers who indicated that there was a relationship	5	12.5
Total	40	100

Open-ended responses were analyzed using descriptive coding, and emerging themes were interpreted alongside quantitative results to support the systematic structural analysis.

Table 6 displays the descriptive analysis findings obtained from the open-ended opinions of chemistry teachers representing their perceptions of the relationship between self-efficacy and augmented reality competencies in line with the systematic structural approach. The teachers' responses indicated an almost equal distribution between those who established a relationship between the two competencies and those who did not, revealing that there are significant disagreements on this issue.

According to the data, 30% of teachers indicated the existence of a relationship between self-efficacy and augmented reality competencies, while emphasizing that this relationship requires support through training to be established effectively. This view indicated that the systematic structural approach is not always internalized in a holistic way in teachers' perceptions. Similarly, 15% accepted that there was a relationship, but stated that this relationship could be strengthened with the development of technological competencies. When these two groups were evaluated jointly, 45% of teachers defined the perception of the relationship as conditional or dependent on development.

On the other hand, 27.5% of teachers clearly stated that self-efficacy and augmented reality competencies are independent structures. This view shows that the systematic structural approach is not always internalized in a holistic way in teachers' perceptions. In addition, 15% of the participants stated that they were undecided about the relationship between the two competencies. This indecisiveness may be due to limited experience with augmented reality applications or the fact that these technologies have not yet been sufficiently internalized in the educational context.

The rate of teachers who directly established the relationship was limited to 12.5%. This rate indicated that there are those who establish the relationship qualitatively, but it also reveals that this perspective is the least represented view in the sample.

IV. Discussions

From the results of the present research, chemistry teachers' scores on the self-efficacy scale for teaching in the laboratory revealed high-level scores. When the analyses on the sub-dimensions of the scale are examined, it was determined that the chemistry teachers have high self-efficacy in the Conducting experiments sub-dimension, medium-high self-efficacy in the Using technology in the laboratory dimension, and high self-efficacy in the Lab safety sub-dimension. This result is consistent with the “Chemistry Teachers’ Self-Efficacy Scale” developed by Turan *et al.* [19] Perception Scale for Teaching in Chemistry Laboratories” study, it was determined that chemistry teachers’ perceptions of pedagogical and technical competence in the laboratory were at a strong level.

In addition, in a review published by Agustian [22], it was emphasized that evidence-based approaches to laboratory teaching increased teachers’ perceptions of self-efficacy and strengthened the effectiveness of teaching environments. These studies are consistent with the findings of the current study and reveal that teachers’ high self-efficacy perception is a common trend in the context of laboratory-based teaching [19, 22].

The results obtained from the study indicated that chemistry teachers have high scores on the Teachers’ Augmented Reality Competency scale. When the analyses regarding the sub-dimensions of the scale are examined, it is possible to show that chemistry teachers have high self-efficacy levels towards augmented reality in the Design, Develop and Modify sub-dimension, Pedagogy, Teaching, Assessment and Feedback sub-dimension, Search, Evaluate and Organize sub-dimension, and Ethics and Safety sub-dimension. This result is parallel to the research conducted by Nikou *et al.* [20] in an international sample and using the TARC infrastructure. In this study, teachers exhibited high self-efficacy levels in the “Design, Develop and Modify”, “Pedagogy, Teaching, Assessment and Feedback”, “Search, Evaluate and Organize”, and “Ethics and Safety” sub-dimensions, and significant relationships were determined between these sub-dimensions.

Augmented Reality (AR) has emerged as a transformative instrument in educational environments, particularly in improving laboratory ethics and safety instruction for chemistry educators. By employing AR technologies, educators can develop immersive experiences that replicate actual laboratory conditions, thereby enhancing the comprehension of safety measures and ethical norms among both teachers and students. Chen, Li, and Tu [23] emphasize the efficacy of a mixed reality-based learning system for chemistry experiments aimed at enhancing chemical laboratory safety education. Their findings indicate that such technologies not only engage learners but also enhance a profound understanding of safety regulations in a controlled, risk-free setting. Moreover, Zhu *et al.* [24] highlight that augmented reality applications can markedly elevate engagement and improve educational results in biochemistry laboratory safety. The interactive characteristics of augmented reality enable learners to visualize perilous situations and suitable reactions, thereby emphasizing the significance of safety protocols in chemical testing. This dynamic learning methodology can enhance knowledge retention and foster a deeper commitment to ethical behaviors in laboratory environments.

The use of augmented reality in education presents several obstacles. Jiménez [25] examines various obstacles, such as budget constraints and differing degrees of technical competence among educators. Surmounting these challenges is essential for realizing the complete potential of AR in promoting an ethical and secure laboratory environment. The incorporation of augmented reality in chemistry teaching offers significant advantages, although it requires meticulous attention to the associated obstacles.

Similarly, in the systematic review conducted by Garzón, Baldiris, and Gutiérrez [26], it was reported that teachers’ perceptions of their efficacy in integrating augmented reality technologies into educational environments were generally high and that these technologies motivated teachers in terms of instructional planning, evaluation, and safe use. The review shows that augmented reality supports teachers’ Technological Pedagogical Content Knowledge (TPACK) construct and that this construct is directly related to their perceptions of efficacy [26].

To assess the relationship between teachers’ self-efficacy in laboratory teaching and their augmented reality competencies, Pearson correlation coefficients were calculated for the Self-Efficacy for Teaching in the Laboratory (SEPTL) and TARC scales. The results indicate that self-efficacy perceptions related to laboratory teaching are independent of competencies in augmented reality technologies. This finding is supported by research conducted by Ripsam and Nerdel [5], which identified a weak rather than strong correlation between digital media self-efficacy and acceptance of augmented reality among chemistry teachers. Therefore, the interdependence between TARC and SEPTL was also observed in a similar context. In addition, an important study by Duc *et al.* [27] supported the present finding by revealing that teachers’ perceptions of augmented reality technologies develop in parallel with technological competence, pedagogical suitability, and experience; these competences are not related to laboratory teaching self-efficacy.

Together, the quantitative findings and the descriptive qualitative results provide a complementary understanding of teachers’ self-efficacy and augmented reality competencies within a systematic structural framework. When the quantitative and qualitative findings are considered together, a complementary pattern emerges. While the correlation analysis indicates no statistically significant relationship between laboratory teaching self-efficacy and augmented reality competencies, qualitative findings reveal that a small group of teachers perceive a meaningful connection between these domains. This suggests that although the relationship is not strong at the population level, individual experiences, beliefs, and contextual conditions shape how teachers interpret the integration of augmented reality into laboratory teaching. Therefore, the qualitative findings provide explanatory depth to the quantitative results by revealing underlying perceptions that are not captured through correlational analysis alone.

The absence of a significant relationship between laboratory teaching self-efficacy and augmented reality competencies may also be explained by contextual factors. In Kazakhstan, access to augmented reality technologies, institutional support, and professional development opportunities vary considerably across schools. While teachers may feel confident in traditional laboratory practices, limited exposure to AR-based instructional training and infrastructure constraints may prevent these competencies from developing in an integrated manner. Therefore, contextual conditions should be considered when interpreting the independence between these two competency domains [14, 26].

The descriptive analysis findings regarding the self-efficacy levels of chemistry teachers towards laboratory teaching, in line with the systematic structural approach, show that the vast majority of teachers evaluate their self-efficacy level as high or moderate. Self-efficacy is a vital factor affecting the efficacy of chemistry educators in laboratory environments. Systematic structural elements, such as institutional support, resource availability, and professional development opportunities, profoundly influence self-efficacy views [19]. Educators frequently face obstacles, including insufficient facilities and restricted access to contemporary equipment, which might diminish their confidence in providing good laboratory instruction [28].

The descriptive analysis findings regarding the competence levels of chemistry teachers towards augmented reality technologies, in line with the systematic structural approach show that half of the teachers perceive augmented reality competence positively; however, a significant proportion think that they have limited competence in this regard. This finding is also consistent with a study conducted by Ibáñez and Delgado-Kloos [29]. The study revealed that teachers' perceptions of the use of augmented reality technologies in education are generally positive; however, they see their competence as limited in terms of pedagogical integration, content production, and technical support. It has been reported that science teachers, in particular, have high attitudes towards technology, but they experience uncertainty in their self-efficacy during the transition to implementation [29].

The differing perspectives among teachers regarding the relationship between self-efficacy and augmented reality competencies may stem from variations in technological experience, training background, and pedagogical beliefs. Teachers who associated the two competencies often emphasized the role of professional development and hands-on experience with AR applications. In contrast, those who perceived them as independent tended to view laboratory teaching as a practice grounded in traditional experimental skills rather than digital innovation. These differences indicate that teachers' beliefs about technology integration play a crucial role in shaping how competencies are conceptualized within a systematic structural approach [30].

The correlation between Self-Efficacy for Teaching in the Laboratory (SEPTL) and the enhancement of AR competences has attracted considerable interest in educational research. Self-efficacy is crucial in teachers' readiness to incorporate modern technologies into their instructional methods. Ripsam and Nerdel [5] investigated educators' perceptions of augmented reality in chemistry instruction, demonstrating a direct relationship between increased self-efficacy and the incorporation of augmented reality technologies. The study confirms that instructors with higher self-efficacy are more likely to implement AR-based educational methods, therefore improving student engagement and learning results.

O'Connor and Mahony [9] examined the influence of augmented reality on students' academic self-efficacy in higher education. Their findings demonstrate that augmented reality not only enhances conceptual comprehension but also cultivates a sense of competence in students. This subsequently affects their motivation and academic performance. Furthermore, the significance of Augmented Reality (AR) in vocational education has been emphasized by Sirakaya and Kilic Cakmak [30], who discovered that AR positively influenced both student achievement and self-efficacy, suggesting a substantial correlation between teaching self-efficacy and the effective application of AR tools in enhancing educational outcomes.

Aldeeb *et al.* [13] highlighted the potential of mobile AR applications in augmenting learning, noting enhancements in students' self-efficacy and motivation when employing these technologies. The results correspond with Srinivasa *et al.* [31], who established that virtual reality applications in practical laboratory environments markedly enhanced students' self-efficacy and attitudes toward learning. These studies collectively highlight the significance of SEPTL in relation to AR, indicating that good training and professional development can improve educators' self-efficacy, hence aiding the incorporation of AR competences that eventually increase educational practices and outcomes.

Chemistry is a science that requires an understanding of abstract concepts and interactions at the molecular level. Integrating a systematic structural approach with Augmented Reality (AR) technology can make this process more accessible and interactive for students. The incorporation of Augmented Reality (AR) in chemistry teaching offers an innovative method to improve student engagement and comprehension of intricate subjects. A systematic structural approach to chemistry instruction, as articulated by Mazzuco *et al.* [32], underscores the significance of organized pedagogical techniques that can be enhanced with interactive augmented reality experiences. These experiences have demonstrated a substantial enhancement in students' capacity to comprehend complex chemical structures and reactions. Nechypurenko *et al.* [33] emphasize the creation and application of augmented reality resources that correspond with systematic instructional methodologies, enhancing the learning environment. The synergistic impacts of various techniques illustrate AR's capacity to promote deeper understanding and persistent engagement in chemistry education, therefore improving overall academic performance.

V. Conclusion

The research findings show that chemistry teachers' self-efficacy for teaching in the Laboratory is generally high. When examined on the basis of sub-dimensions, it was determined that teachers have high self-efficacy in conducting experiments and laboratory safety, and medium-high self-efficacy in using technology. Similarly, the scores obtained by Teachers from the Augmented Reality Competency (TARC) scale are also generally high.

From a classroom practice perspective, the findings suggest that high laboratory self-efficacy alone does not guarantee effective integration of augmented reality technologies. Teachers may require structured guidance on how AR can be pedagogically aligned with laboratory activities. Professional development programs should therefore focus on bridging traditional laboratory practices with digital instructional tools, enabling teachers to transfer their confidence in laboratory teaching into technology-enhanced learning environments.

However, according to the correlation analysis, no statistically significant relationship was found between teachers' self-efficacy levels for laboratory teaching and augmented reality competencies. This result shows that the 2 competency types can be evaluated independently of each other in teachers' perception. Descriptive analysis findings also revealed that teachers generally evaluate their self-efficacy levels as high or medium, and that there is a wider distribution in their perception of competence towards augmented reality technologies. Qualitative data showed that some teachers established a relationship between the two competencies, while others viewed these two competencies as independent skills.

The incorporation of AR in chemistry teaching offers a new opportunity to improve teachers' self-efficacy and skills. A systematic structural methodology that integrates AR technologies enhances immersive learning experiences, allowing educators to visualize intricate chemical ideas. The interactive aspect of teaching enhances chemistry professors' confidence in their pedagogical abilities, enabling them to engage students more effectively. Research indicates that increased self-efficacy is associated with superior teaching practices, resulting in more effective learning outcomes. AR tools enhance educators' information delivery through real-time feedback and interactive simulations, fostering a deeper comprehension of chemistry subjects. Moreover, structured training techniques accompanying AR integration guarantee that educators acquire the requisite skills to utilize these technologies effectively in their courses. Thus, the integration of augmented reality with structured educational frameworks is expected to produce significant advantages in teaching methods, resulting in enhanced and more immersive learning experiences in the chemistry classroom.

In conclusion, this study reveals that chemistry teachers have a high level of self-efficacy perception in both laboratory teaching and augmented reality applications, while it also shows that these two competency types are not fully integrated structurally in teachers' perception.

The absence of a significant relationship between laboratory teaching self-efficacy and augmented reality competencies may also be explained by contextual factors. In Kazakhstan, access to augmented reality technologies, institutional support, and professional development opportunities vary considerably across schools. While teachers may feel confident in traditional laboratory practices, limited exposure to AR-based instructional training and infrastructure constraints may prevent these competencies from developing in an integrated manner.

In this study, the self-efficacy perceptions and attitudes of high school chemistry teachers towards AR were evaluated based on the systematic structural approach. The findings revealed that teachers generally have high self-efficacy levels; however, they developed different perceptions regarding the relationship between augmented reality technologies and laboratory teaching. In this context, the following recommendations were developed in line with the principles and components of the systematic structural approach:

(1) AR-supported teaching practices should be integrated into teacher training programs within a systematic structure. Pre-service teachers should experience the process holistically with structured AR scenarios from the teaching objectives to the evaluation stage.
(2) In-service training courses should provide structured instruction on integrating augmented reality technologies into pedagogical planning and content organization. Such training should strengthen not only teachers' technical skills but also their skills in planning and associating teaching strategies.
(3) Guidance materials should be developed to establish a conceptual connection between laboratory teaching and augmented reality applications. These materials should present dimensions such as experiment design, safety, and evaluation in a structured manner in the AR environment.
(4) In line with the principles of instructional design based on a systematic structural approach, individual and collaborative reflective activities that support the development of teachers' self-efficacy should be implemented. Especially, opportunities for analyzing and evaluating the experiences of teachers who teach with AR applications should be increased.
(5) National education policies should be rearranged to support the systematic structuring of digital pedagogical competencies and should include examples of instructional designs specific to the use of AR.
(6) Interdisciplinary modules that simultaneously develop teachers' laboratory teaching and AR competencies should be created, and the relationships teachers establish between these areas should be supported.
(7) In future research, the relationship between self-efficacy and AR competencies in different branches should be examined in depth with qualitative and experimental methods in line with the systematic structural approach.

These recommendations aim to develop both pedagogical and technological competencies of teachers by basing them on systematic and structural foundations. Effective integration of educational technologies is possible not only with technical tool knowledge, but also with structured instructional planning. Therefore, professional development models that focus on a systematic structural approach will contribute to the sustainable strengthening of teacher competencies.

Conflict of Interest

The author declares no conflict of interest.

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