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Analysis of the Relationships Between University Students' Laboratory Self-Efficacy Beliefs, Science Process Skills and Achievement in Chemistry Courses

Ainur Sailaubay[a], Nurbala Myrzakhmetova[a], Mehmet Tunçel[b], & Kazhymukan Kishibayev[a]

* Corresponding author
Email: ainurajks@mail.ru
a. Kazakh National Women's Teacher Training University, Almaty, Kazakhstan.
b. Niğde Ömer Halisdemir University, Türkiye.

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ABSTRACT
It is a widely accepted view among educators that chemistry education should include objectives to develop scientific thinking, laboratory competences and science process skills in addition to chemistry. The aim of this study is to investigate the relationships between laboratory self-efficacy beliefs and science process skills of chemistry department students and their chemical technology course achievement. The study was conducted in the autumn term of the 2023-2024 academic year in the chemistry departments of three universities in Kazakhstan. The study, which was conducted with relational survey model on the basis of quantitative research paradigm, included 198 students studying in chemistry departments. The data of the study were collected with 'Laboratory self-efficacy beliefs scale' and 'Science process skills scale'. The participants' laboratory self-efficacy beliefs were above moderate, and their science process skills were at a moderate level, according to the study's conclusions. Chemistry department students' laboratory self-efficacy and science process skills did not differ by gender. Correlation analyses revealed significant and positive relationships between students' achievement in chemical technology course and their laboratory self-efficacy beliefs and science process skills in the chemistry department. Regression analyses revealed that the participant students' science process skills, in particular, significantly predicted their performance in the chemical technology course.

KEYWORDS
Chemistry courses; university students; laboratory self-efficacy; science process skills; achievement.

INTRODUCTION

Chemistry education, which plays an important role in science education and begins in the eighth grade of primary school, is included in the compulsory curriculum at all educational levels up to university. For an adequate science education, it is of great importance to teach the concepts in chemistry course correctly as well as other science courses. In our education system, where teaching services cannot be fully realised, chemistry education practices encounter a number of challenges (Cooper & Klymkowsky, 2013; Pilot & Bulte, 2006). In the learning-teaching process of chemistry education, it has been determined that various constants, units and symbols that should be learnt together with chemistry concepts are not fully learnt by students. Due to various deficiencies in the chemistry curriculum, chemistry concepts cannot be taught in accordance with the goals set for the students. Traditional rote methods are used to teach chemistry concepts to students, which fails to stimulate their interest in learning more (Garkov, 2006; Stolk et al., 2005).

Since the mid-19th century, laboratories have been accepted as one of the basic elements of science teaching. Laboratories are seen as the most appropriate environments for students not only to learn but also to show their performances (Blosser, 1983). In chemistry education, students learn by doing-living. Therefore, laboratory activities are necessary in chemistry education and students can gain science process skills through these activities. Laboratory activities in chemistry course provide easier understanding of the subject, gain experience for students in planning the experiment and using their own knowledge. During teaching, students make observations and get detailed information. It also increases students' interest in science lessons (Blosser & Helgeson, 1990).

The laboratory is an environment that allows students to express the subjects and concepts they have gained through first-hand experiences and to associate them with other concepts (Arnado et al., 2022; Hofstein & Lunetta, 2004). Working in the laboratory improves problem solving skills, provides meaningful learning, increases analytical thinking skills, improves self-confidence, and helps to establish the relationship between daily life and science (Forcino, 2013; Shapiro et al, 2015). During laboratory applications, more meaningful and permanent learning occurs when students access information using their own solutions, associate it with their prior knowledge, and apply it in their daily lives. In this regard, it is essential to plan laboratory activities that provide meaningful and permanent learning in chemistry education. When the literature is examined, the studies on laboratory method in chemistry education largely include the difficulties encountered in the laboratory, attitudes towards the laboratory and various techniques used in the laboratory method (Lowe et al., 2012; Olympiou & Zacharias, 2011).

According to Ausubel, the laboratory helps students develop skills in evaluating the method and meaning of science, generating solutions and results, and understanding the nature of science (Hofstein & Lunetta, 1982). The prerequisite that should be acquired in the process of conducting experiments, observations or investigations in laboratories is science process skills. These skills include measuring, classifying, recording data, establishing number and space relationships, predicting, determining variables, interpreting data, drawing conclusions, developing theories or models, making operational definitions, formulating hypotheses and experimenting (Carey et al., 1989; Hodson, 1996). The science process skills approach attempts to develop these skills through laboratory activities. This approach should not be considered independently of others. Other approaches can be used to learn scientific processes, but the science process skills approach is the most effective (Al-Naqbi & Tairab, 2006; Nirmala & Darmawati, 2021). Studies on the effects of students actively engaging in the learning process as opposed to memorization of information have been conducted recently in the field of science education, and positive findings have been reported (Boddy et al, 2003; Musheno & Lawson, 1999; Rivet & Krajcik, 2004; Wallace et al., 2003; Zacharia, 2003).

It is a widely accepted view among educators that chemistry education should include goals to develop scientific thinking and skills related to scientific processes in addition to chemistry. Scientific thinking can be defined within the framework of processes such as logical thinking, problem solving, induction and deduction (Jegstad & Sinnes, 2015; Landa et al., 2020). According to Garcia (2005), there are two objectives for science education. The first of these is to help students comprehend the nature of science and to think critically and solve problems. The second objective is to equip students with the scientific knowledge and skills necessary to develop their scientific literacy.

Scientists are not the only ones who use science process skills. In addition, people in general and students, in particular, are expected to be keen observers of the various issues that arise in daily life, to understand the distinctions and issues pertaining to both their surroundings and them, to challenge these issues, and to look up alternative solutions. According to Rollero (1998), it is unrealistic to expect people who lack or are unable to use science process skills to overcome obstacles and succeed in life or in business. Science education that enables students to think and research to better understand nature and natural events by directing them to nature and natural events, to solve problems within their own knowledge and skills, and to create new inventions and discoveries is the desire of all contemporary societies. The creation of such an environment and the acquisition of the skills related to scientific processes by students is possible with an education and training system prepared for the teaching of these skills (Adjapong, 2019; Carin & Bass, 2001). Students can only acquire these skills by applying scientific thinking techniques and methods, as demonstrated by the skills that have gained prominence in the last ten years. Students' future scientific perspectives, their development of science process skills like observation, inference, and inquiry, and their interest and attitude towards nature and science are all positively impacted by their experience gained through natural ways based on scientific methods (Eshach & Fried, 2005; Patrick et al., 2009). Science process skills are cognitive abilities that are applied in the creation of knowledge, problem identification, and formulation of the outcomes (Lind, 1998).

The "Science-A Process Approach (SAPA)", which popularised science process skills, divided the skills into two classes as basic and integrated skills. Basic science process skills are defined as observation, inference, measurement, communication, classification, and prediction. The skills involved in the integrated science process are defined as operational definition, hypothesis formation, organising and interpreting data, experimenting, and model building (Padilla, 2018). Science process skills have been explained and grouped in different ways by many researchers. According to the existing literature, science process skills are classified as causal, experimental process skills, combined/integrated process skills (Harlen, 1999; Kurniawati, 2021; Miles, 2010; Özyer, 2024). The American Association for the Advancement of Science (AAAS) recognizes this same distinction and uses these categories in their S-APA program for primary education (Inayah et al., 2020). Basic process skills must be acquired by every student, particularly because these skills are also used in daily life. Forming the development of mental skills by acquiring basic skills in the first place is the basis for learning and using higher and complex skills (Derilo, 2019). The phrase "combined process skills" was also used in place of "integrated process skills." When the classifications are examined, it is seen that the skills in the content of the classifications are generally related to designing the research, determining the research question, collecting and evaluating evidence, and communicating (Harlen, 1999).

Students that possess science process skills and laboratory application skills actively engage in the learning process, promote meaningful learning by developing their research and questioning abilities, and prevent rote learning by taking ownership of their education (Mattheis & Nakayama, 1988; Nirmala & Darmawati, 2021; Roth & Roychoudhury, 1993; Sekerbayeva et al., 2023). Students need to gain laboratory application competencies and science process skills in order to take advantage on the rapid developments in science. This scenario highlights the value of chemistry courses where students apply science process skills by actively engaging in the process and learning by doing, as well as the significance of incorporating these skills into education. Students need access to a laboratory setting where they can conduct experiments and observation-based learning activities to develop their science process skills. To optimise the level of students' science process skills, the curriculum of science courses in general and the unit activities of the chemistry course in particular should be comprehensive and inclusive of these skills, in addition to the learning environment. As outlined by Todd and Shinzoto (1999), fostering students' creative thinking abilities, enhancing their motivation across all subject areas, and equipping them with the research and questioning skills necessary for success are crucial for the development of high-achieving and talented students in the future. However, above all, teachers, who carry out instruction and training, must be knowledgeable about science process skills and laboratory applications. In addition, research in this field reveals that most of the students studying in science fields do not receive sufficient information about science process skills and laboratory practices in their pre-vocational education or do not use the information they receive in practice (Baker & Piburn, 1991; Bellová et al., 2018; Sukarno &

Hamidah, 2013). This study will contribute to the field in terms of revealing the competences of chemistry department students in terms of science process skills and laboratory applications. These make the research significant, as it assessed student achievement and looked at the science process skills and laboratory practices of chemistry course prospective teachers. The study's significance is further increased by revealing how aware chemistry department students are of science process skills, laboratory procedures, and the context surrounding those procedures. Thus, the aim of this research is to identify the relationships between the achievement of learners in chemical technology course and their science process skills and laboratory self-efficacy. Within this framework, the study sought to address the following questions:

- What is the level of chemistry department students' science process skills, laboratory self-efficacy and chemical technology course achievement?
- Do chemistry department students' science process skills and laboratory self-efficacy differ based on gender?
- Is there a significant relationship between chemistry department students' science process skills, laboratory self-efficacy and chemical technology course achievement?

METHOD

Since the aim of this study was to determine and evaluate the Integrated Process Skills (IPS) of pre-service science teachers, the relational survey model was used in the study. According to Jatana et al. (2013), what should be considered in the survey model is to observe and determine the current situation in an appropriate way without changing or affecting the existing situation. Firstly, the science process skills and laboratory self-efficacy of the students enrolled in the Chemistry Department were assessed in this context. The relationships between the participant students' academic achievement in the chemical technology course and their science process skills and laboratory self-efficacy were then discussed.

The research was conducted on Chemistry Department students of 3 universities in Kazakhstan in the autumn semester of 2023. 198 first-year Chemistry majors from these three universities make up the study group for the study. Having completed the chemical technology course, which is taught in the department's first year, and willingly participating in research procedures were requirements for choosing the participant students. There were 93 male and 105 female students that took part.

Data Collection Tools

A questionnaire was administered to students in the chemistry department, and scores from chemical technology course at the end of the semester were used to compile the data for the study. Chemical technology course is taught as three course credits in the first year of the chemistry department at the three universities that make up the study's sample. With the required authorization, the student affairs departments of the relevant faculties provided the final scores of chemical technology course to the students. The hundredth-grade system was used to arrange the student achievements in chemical technology course. Students who took part in the study completed questionnaires called the "Science Process Skills Test" and the "Laboratory Self-Efficacy Scale."

Laboratory Self-Efficacy Scale

The scale developed by the researchers was used to examine the self-efficacy of the participating chemistry department students towards laboratory use. Laboratory Self-Efficacy Beliefs Scale consists of 15 items in 5-point Likert type. The scale has a lowest possible score of 15 and a maximum score of 75. It was concluded that the findings obtained from the validity and reliability analyses of the scale were significant and acceptable in terms of psychometric properties. The scale's single factor, which displayed a single-factor structure, was found to account for 41.15% of the variance overall based on the factor analysis results. The scale's calculated KMO (Kaiser-Meyer-Olkin) value was 0.91 within the construct validity framework, and the Barlett's Test value was significant at the level of ($p<0.001$). A reliability coefficient of $\alpha = 0.91$ was reported for the overall scale.

Science Process Skills Scale

The "Science Process Skills Test," created by Burn et al. (1985), was used to assess the science process skills of chemistry department students. In this 36-question multiple-choice test, the skills that were tried to be measured were defining variables (12 questions), defining a process (6 questions), formulating and defining hypotheses (9 questions), interpreting graphs and data (6 questions) and designing research (3 questions). The scale assigns a score of 1 for correct answers and a score of 0 for inaccurate ones. High scores indicate a high degree of science process skills. Burn et al. (1985) used internal consistency (KR-20) analysis to examine the test's reliability and determined that it had a 0.82 reliability coefficient. A reliability study using the Kazakh language yielded a 0.80 reliability coefficient for the scale.

Data Analysis

The science process skills test's multiple-choice answers were assessed to determine whether they were correct or incorrect. Subsequently, the SPSS 27.0 software was utilised, with accurate responses being coded as 1, and inaccurate responses being coded as 0. Laboratory self-efficacy scale data were entered into the programme by scoring between 1 and 5 for each item. Prior to using the significance and relationship tests to find the answers to the study's sub-questions, it was determined whether the data followed normal distribution. For this purpose, skewness and kurtosis coefficients of the data were determined first. The findings demonstrated that the science process skills and laboratory self-efficacy data from chemistry department students met the requirements of normal distribution. Based on this, the gender-based comparison of the science process skills and laboratory self-efficacy of chemistry department students was conducted using the Independent Samples t-test. Pearson Product Moment Correlation Coefficient and Multiple Regression Analysis techniques were used to analyse the relationships between chemistry department students' science process skills and laboratory self-efficacy and their academic achievement in chemical technology course. The results were assessed at the

0.05 significance level and the analyses were carried out using the SPSS 27.0 computer programme.

FINDINGS

The science process skills test results of pre-service science teachers in Kazakhstan were examined in terms of their sub-dimensions in the first sub-problem of the study. Table 1 displays the number of questions, mean ($\bar{x}$), and standard deviation (SD) values related to the pre-service teachers' scores.

Table 1.

Science Process Skills, Laboratory Self-Efficacy and Chemistry Course Achievement Levels of Chemistry Department Students

Science Process Skills Dimensions	Number of Questions	Mean	Std. Deviation
Identifying and Controlling Variables	12	7.9	4.5
Making Operational Definition	6	3.6	2.6
Formulating Hypothesis	9	5.5	3.5
Analysing Data and Reading Graphs	6	4.1	2.1
Experimenting	3	2.2	1.1
Integrated Science Process Skills Total	36	23.2	10.6
Laboratory Self-efficacy		3.4	0.7
Chemical Technology Course Achievement		57.3	21.6

As displayed in Table 1, the mean and standard deviation of the students' responses to the science process skills test were 23.2 and 10.6, respectively. The highest score that could be obtained from the test was 36. According to these data, it could be argued that chemistry department students' level of acquiring science process skills was moderate. The mean score of the participant students' laboratory self-efficacy scale was 3.4 and the standard deviation was 0.7. The highest mean score that the participant students could get from this scale was 5.00. These results indicate that the self-efficacy of chemistry department students in laboratory applications was higher than moderate.

The second sub-question of the study was whether the science process skills and laboratory self-efficacy of chemistry students differed according to gender variables. An answer to this question was sought. In this context, the analyses performed with the Independent Samples t-test are presented in Table 2.

When the science process skills levels of chemistry department students were compared based on the gender variable, the results revealed that there was no significant difference in either the sub-dimensions or the total scores ($p>0.05$). Males were generally better at the science process skills than females, even though there was no statistically significant difference. In the laboratory self-efficacy variable, there was also not a significant difference between the mean scores of the two genders ($p>0.05$). However, compared to their male peers, female students demonstrated higher achievement in laboratory self-efficacy.

Table 2.

Analysis of Chemistry Department Students' Science process skills and Laboratory Self-Efficacy by Gender

Science Process Skills Dimensions	Gender	N	Mean	Std. Deviation	t	p
Identifying and Controlling Variables	Female	105	7.85	4.39	-0.10	0.92
	Male	93	7.91	4.61		
Making Operational Definition	Female	105	3.50	2.61	-0.62	0.54
	Male	93	3.73	2.54		
Formulating Hypothesis	Female	105	5.45	3.50	-0.16	0.87
	Male	93	5.53	3.41		
Analysing Data and Reading Graphs	Female	105	3.90	2.25	-1.34	0.18
	Male	93	4.31	1.99		
Experimenting	Female	105	2.19	1.08	0.45	0.65
	Male	93	2.12	1.17		
Integrated Science Process Skills Total	Female	105	22.90	10.68	-0.39	0.69
	Male	93	23.60	10.55		
Laboratory Self-efficacy	Female	105	3.43	0.76	1.70	0.09
	Male	93	3.26	0.66		

The relationships between chemical technology course achievement of chemistry department students, science process skills sub-dimensions and laboratory self-efficacy score were analysed with 'Pearson product-moment correlation coefficient' and the results are displayed in Table 3.

Table 3

Correlation Analysis Results Related to Science Process Skills, Laboratory Self-Efficacy and Students' Chemical Technology Course Achievement

Variables		1	2	3	4	5	6	7
1st Chemical Technology Course Achievement	r	1						
2. Laboratory Self-efficacy	r	.299**						
	p	<0.001						
3. Identifying and Controlling Variables	r	.644**	.311**					
	p	<0.001	<0.001					
4. Making Operational Definition	r	.671**	.322**	.925**				
	p	<0.001	<0.001	<0.001				
5. Formulating Hypothesis	r	.664**	.348**	.907**	.925**			
	p	<0.001	<0.001	<0.001	<0.001			
6. Analysing Data and Reading Graphs	r	.621**	.219**	.711**	.744**	.786**		
	P	<0.001	0.002	<0.001	<0.001	<0.001		
7. Experimenting	r	.456**	.481**	.495**	.562**	.565**	.466**	
	P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
8. Integrated Science Process Skills Total	r	.694**	.352**	.958**	.964**	.970**	.832**	.614**
	p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

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

The table shows the correlation between students' performance in chemical technology course and the following aspects of the science process skills test: 'Identifying and Controlling Variables' (r=0,64; p<0,01); 'Making Operational Definition' (r=0,67; p<0,01); 'Hypothesising' (r=0,66; p<0,01); 'Analysing Data and Reading Graphs' (r=0,62; p<0,01); 'Experimenting' (r=0,46; p<0,01); and the test as a whole (r=0,69; p<0,01). A high, positive, and significant relationship was found between science process skills and their sub-dimensions and achievement. In addition, there was a correlation between laboratory self-efficacy and students' achievement in chemical technology course (r=0,30; p<0,01) as well as the total of their integrated science process skills (r=0,35; p<0,01). Thus, it can be concluded that students in the chemistry department achieve more in chemical technology course as their science process skills and laboratory self-efficacy increase.

Table 4 presents the results of "Multiple Regression Analysis," which was used to examine the relationship between science process skills and laboratory self-efficacy scores of chemistry department students and their performance in chemical technology course.

Table 4.

Multiple Regression Analysis Results Related to Science Process Skills and Laboratory Self-Efficacy and Students' Chemical Technology Course

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	-t-	P
(Constant)	24.23	5.30		4.57	<0.001
Laboratory Self-Efficacy	1.86	1.65	0.062	1.13	0.26
Science Process Skills Total	1.15	0.09	0.614	10.30	<0.001

$R=0.65$; $R^2=0.42$; $F=86.65$; $p<0.01$

The data in Table 4 demonstrate that "science process skills" and "laboratory self-efficacy" showed a significant relationship on the dependent variable (Chemical technology course achievement) as a result of the multiple regression analysis between the related variables and students' achievement in chemical technology course ($R=0,65$; $R^2=0,42$; $F=86,65$; $p<0,01$). In the chemistry course, two independent variables-the laboratory self-efficacy and science process skills-accounted for about 42% of the achievement. The standardised regression coefficients were employed to determine the relative importance of the related variables, which were "science process skills" ($\beta = 0.514$), "laboratory self-efficacy" ($\beta = 0.268$), and "motivation for communication" ($\beta = 0.062$), in relation to the independent variables and chemical technology course achievement. The findings indicate that the variable most predictive of chemical technology course achievement is students' competence in science process skills.

DISCUSSION

This study investigated the relationships between students' achievement in chemical technology course, their self-efficacy in laboratory practice, and their science process skills. First, the participant students' science process skills, self-efficacy in the laboratory, and chemical technology course achievement were detailed. The study's conclusions showed that while students in the chemistry department had self-efficacy above the moderate level in their laboratory practices, their science process skills were only at a moderate level. In a similar vein, a moderate level was determined by analysing the students' achievement in the chemical technology course using a hundred level system.

Students in the chemistry department are only partially successful in identifying variables related to a problem, formulating hypotheses, experimenting, analysing data and reading graphs when the fundamental aspects of science process skills are looked at generally. Nonetheless, it is evident that they are only partially proficient in making operational definitions, which is a crucial component of science process skills. In an investigation to determine the pre-knowledge levels of prospective science teachers regarding science process skills and their performance in applying these skills, Yıldırım et al. (2013) found that the majority of pre-service science teachers lacked sufficient comprehension of science process skills, some students confused concepts in the steps of the science process skills with other concepts, and their performance in applying these skills and creating activities was fairly low. Science process skills are relevant to all branches of science that are associated with science content, not just certain branches of science (Harlen, 1999). Because these skills and domain knowledge are complementary, it is impossible to think of a solution to a problem without having science process skills or domain knowledge. While it's possible that the majority of students won't pursue careers in science, it is important to keep in mind that each person is an individual with the capacity to observe the world around them, ask questions, analyse data, recognise problems, and find solutions. Consequently, it is challenging for chemistry students to succeed in business if they do not apply science process skills (Rillero, 1998). On the other hand, laboratories and students' competencies play a crucial role, particularly in chemistry departments. The study revealed that the participant students' self-efficacy in laboratory was only partially high. According to Lang et al. (2005), a student's competence in chemistry laboratory has a positive impact on the learning environment, the teacher-student dynamic, and the students' course achievements.

Science process skills and laboratory self-efficacy of chemistry students were analysed based on gender variable in another sub-problem of the study. The study's conclusions indicate that there was no significant difference in the participant students' science process skills or laboratory self-efficacy by gender. However, female students obtained high scores on the laboratory self-efficacy scale and male students scored highly on the science process skills scale. The results of Akar (2007), Beaumont-Walters and Soyibo (2001), Huppert et al. (2002), and Wititsiri (2007) are similar to these findings. In the study conducted by Akar (2007) on pre-service teachers, no significant difference was found in any dimension of science process skills according to gender. As a result of this study, the fact that prospective teachers' science process skills do not differ significantly by gender may be an indication that they have equal opportunities throughout their education.

The study's final finding concerns the relationship between chemical technology course achievement, laboratory self-efficacy, and science process skills among chemistry majors. The results of correlation and regression analyses demonstrated a positive and significant relationship between the academic achievement of students in the chemical technology course and their science process skills and laboratory self-efficacy. Science process skills are a well-known instrument utilised in the creation of scientific knowledge. According to Dowing and Filer (1999), there is a correlation between students' achievement and competencies in science and their ability to use science process skills. The results of the study by Abd Rauf et al. (2013) showed that the groups with more science instruction had better outcomes with science process skills. Helseth et al. (1981), for instance, found a moderately significant and positive relationship between the degree of science process skills possessed by prospective teachers and their achievement in the biology course. A strong positive relationship between the students might not have developed if they had obtained particularly high academic achievement scores through rote memorization. As a result, their science process skills might not have been as strong. For this reason, it is believed to be essential that students apply their science process skills to their learning. As a result, students' knowledge will become permanent.

CONCLUSION AND RECOMMENDATIONS

The study's findings indicate a strong positive correlation between the chemistry achievement, laboratory self-efficacy, and science process skills of prospective teachers. Previous research (Helseth, Yeany, & Barstor, 1981; Sittirug, 1997) also demonstrates a positive correlation between academic achievement and science process skills. Furthermore, it is expected that students who successfully complete laboratory courses will be able to think critically, gain scientific knowledge, and develop an analytical approach to thinking. Learning is thought to be facilitated by using laboratory and experiment methods when teaching chemistry courses. It will stimulate students' curiosity about research, which will aid in the development of science process skills. Additionally, regression analyses showed a strong correlation between students' academic achievement scores in chemistry courses and their science process skills. Therefore, it could be recommended that the chemistry department's courses be designed to help students' science process skills be strengthened more effectively. A greater emphasis can be placed on laboratory-based courses aimed to build science process skills and laboratory competencies in undergraduate chemistry programmes. Science process skills can be incorporated into theoretical courses in chemistry education.

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