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THE IMPORTANCE OF INTEGRATED STEM LEARNING IN CHEMISTRY LESSON: PERSPECTIVES FROM HIGH SCHOOL AND VOCATIONAL SCHOOL CHEMISTRY TEACHERS

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Abstract

Different goals of high schools and vocational schools in Indonesia become the main factor causing the distinction of preparedness of chemistry teachers in using the Science, Technology, Engineering, and Mathematics (STEM) approach in their teaching. Yet the High School Chemistry Teachers (HSCT) and Vocational School Chemistry Teachers (VSCT) need to have positive perceptions about STEM since it offers students meaningful chemistry learning. Through an explorative survey method, this research investigated in-service chemistry teachers' perspectives toward the potential of STEM learning in high school and vocational schools of chemistry. A number of 131 in-service chemistry teachers (82 HSCT and 49 VSCT) from Yogyakarta, Indonesia was voluntarily participated in this research through a saturated sampling technique. Perception Scale on STEM (PC-STEM) consisting of 54 closed-ended questions and seven open-ended questions were used to collect the data. Data analysis techniques involved one-way MANOVA testing, descriptive statistics, and content analysis with interpretive coding. The findings showed that HSCTs' and VSCTs' perspectives toward STEM were in the good category. Thus, integrated STEM learning is potential to be used in chemistry lessons at high school and vocational school. However, there were not any statistically significant differences between HSCT and VSCT participants' perceptions of how STEM was being used to teach chemistry. Unfortunately, despite their perception being good, both groups of teachers signified a poor experience in applying STEM in their chemistry lessons. Therefore, teachers' professional development program about STEM is needed for chemistry teachers to successfully implement STEM-based chemistry learning.

Keywords – Integrated STEM learning, Chemistry lessons, Perspectives, High school chemistry teachers, Vocational school chemistry teachers.

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1. Introduction

In the modern era, humans are faced with a large amount of knowledge about science and technology, including problems that arise in everyday life. The Industrial Revolution 4.0 era's global economy and technological advancements call for the availability of human resources that are not only highly skilled but also capable of approaching challenges in their environment from a variety of angles that may entail science and technology. All parties, including academics, researchers, and education observers, are aware of and have anticipated such circumstances. Students' perspectives on how to learn, communicate, and interact with their surroundings have evolved as a result of the demand for these competencies. One of them is the application of STEM (Science, Technology, Engineering, and Mathematics) as a foundation for future success and as a significant component of educational reform efforts (Bullock, 2017; Tan, 2018).

As an initiative to advance the educational system, the integrated STEM approach has drawn attention on a global scale (Tan, 2018). Numerous programmes have embraced STEM as a key area of concentration for boosting global competitiveness (Breiner, Harkness, Johnson & Koehler,, 2012). Students who participate in STEM programmes can improve their quantitative skills (Reid & Wilkes, 2016), develop an interest in learning and a career in the STEM fields (Miller, Sonnert & Sadler, 2018; Shahali, Halim, Rasul, Osman & Mohamad-Arsad, 2019; Franz-Odendaal, Blotnicky, French & Joy, 2016; Jones, Childers, Corin, Chesnutt & Andre, 2018; Chachashvili-Bolotin, Milner-Bolotin & Lissitsa, 2016), develop analytical thinking skills and attitudes towards science learning (Chonkaew, Sukhummek & Faikhamta, 2016), and quality of teachers (Du, Liu, Johnson, Sondergeld, Bolshakova & Moore, 2019). The ability to achieve in school and at the next level can therefore be given to students if STEM training is continued (Wendt, Rockinson-Szapkiw & Cordes, 2018). STEM empowers students to adapt and succeed in a changing world, including changes in education.

As part of the educational field, integration of STEM learning should be incorporated because STEM learning has the potential to train students how to solve problems in real-world situations (Aydin-Gunbatar, Tarkin-Celikkiran, Kutucu & Ekiz-Kiran, 2018). This integrated STEM learning offers the linking of chemistry concepts with students' lives. Since many students still have trouble digesting the knowledge they have learned about chemistry, the integration of STEM learning could help solve the issue of a lack of experience applying the fundamental concepts (Scaramozzino, 2010). Most students who studied chemistry find that chemistry lessons are not beneficial for their lives (Wiyarsi, Pratomo & Priyambodo, 2020). That is, recent chemistry lessons are only oriented on the mastery of chemistry topics regardless of their potential for application in students' lives. The students argue that chemistry topic is too abstract and these concepts are not applicable to their lives. This such of learning situation leads to a diminishing number of students who choose chemistry as their future major and career (Craig, Verma, Stokes, Evans & Abrol, 2018). Thus, fostering students' interest in studying chemistry should be conducted.

Chemistry serves as a subject that must be comprehended by either high school or vocational school students, making student motivation in learning it a crucial issue in chemistry lectures (Wiyarsi et al., 2020). However, high schools and vocational schools in Indonesia have different goals. Students at high school are prepared to continue their studies in higher education institutions. Therefore, the primary objective of high school students is to master learning content, including chemistry content. Still, in mastering chemistry content, high school students should have a good comprehension of chemistry. A good comprehension of chemistry could be fostered if students could apply chemistry content to the application in their real-world problems (Tuong, Nam, Hau, Tien, Lavicza & Hougton, 2023; Fitriyana, Pratomo, Wiyarsi & Marfuatun, 2023). For instance, students could understand the framework of corrosion phenomena and describe it using the redox reaction concept (Ghalkhani & Esmaeili, 2022). In this case, students will ultimately learn the application of the redox reaction concept, not only the theoretical framework of those concepts.

Phrased differently, different aim is set for students at vocational school. Students at vocational school are prepared to enter work life just after they have graduated. Thus, students at vocational schools are offered several vocational competencies, e.g., energy and mining, technology and engineering, health and social work, agribusiness and agrotechnology, marine, tourism, business and management, etc. Students could choose one of these competencies as their major. Hence, after they are graduated, students could pursue any careers that relate to these competencies. To meet such requirements, students at vocational schools should have good skills related to their competency field. That is, chemistry lessons at vocational could promote students' skills related to specific competencies that are chosen by students. As a result, teaching chemistry in vocational schools should improve both students' vocational proficiency and the relevance of chemistry content in students' daily lives (Holbrook & Rannikmae, 2007). To illustrate, students who choose technology and engineering competency (e.g., automotive engineering) when they are studying hydrocarbon topic, they could correlate the concept of hydrocarbon with vehicle case contexts such as fuel oil and lubricating oils for vehicles (Febrianto, Wiyarsi, Partana & Sulistyo, 2019).

A lot of studies have also characterised integrated STEM learning. According to Bryan, Moore, Johnson and Roehrig (2015), integrated STEM learning involves the teaching and learning of disciplinary knowledge, such as science, chemistry, and mathematics, while including the practices of engineering-relevant technologies. Because vocational schools must develop students' skills, the application of STEM learning is promising to boost students' motivation and enthusiasm for learning chemistry. Furthermore, although high school and vocational school have different goals, the integration of STEM in these two different levels of education is needed as an effort to meet these issues. However, to achieve these goals, chemistry teachers, either at high school or vocational school, should have a good framework for STEM learning integration. These different aims making high school and vocational school chemistry teachers may have different perspectives towards STEM integration.

Chemistry teachers should possess the necessary skills, such as Technological Pedagogical Content Knowledge (TPACK) while creating STEM-based chemistry learning. In this situation, chemistry teachers should take into account their technological, pedagogical, and content knowledge while planning specific STEM-based chemistry lessons for their classrooms (Aydin-Gunbatar, Ekiz-Kiran & Oztay, 2020). Vossen, Henze, De Vries and Van Driel (2019) assert that using TPACK for STEM requires teachers to develop a STEM-based lesson plan, implement it, and work with students to incorporate their understanding of science and mathematics into their design. Because of this, chemistry teachers need to be able to effectively cover the engineering design process in their classes. Unfortunately, chemistry teachers may have diverse TPACK competencies in high school and vocational schools. They may have developed these various TPACK competencies as a result of their high school or vocational school experiences with STEM-based chemistry education. Since it promotes the successful implementation and significance of STEM, chemistry teachers' perspectives on integrating STEM-based chemistry learning must also be investigated in place of experiences. Prior to widespread implementation, as a measure of success in learning chemistry, the knowledge and perception of chemistry teachers about STEM aims to enable chemistry teachers to implement and integrate STEM in learning activities properly. Therefore, we need a way to explore teacher knowledge about STEM, including those relating to strategies for implementing STEM, the advantages of using STEM in learning activities, to the challenges and dilemmas in integrating STEM into the learning process, one of which is in learning chemistry. In order to determine if teachers are prepared to include STEM in chemistry instruction, it is necessary to investigate and compare the perspectives of chemistry teachers from high school and vocational high schools towards STEM learning in chemistry lesson.

To direct this investigation, the subsequent research questions are expanded upon.

- What initial knowledge do high school and vocational high school chemistry teachers have regarding the use of an integrated STEM approach in chemistry learning?

- What is the level of the chemistry teachers' perspectives regarding employing an integrated STEM approach to chemistry instruction in high school and vocational high school?
- Are there differences in the perspectives of high school and vocational high school chemistry teachers in applying an integrated STEM approach to chemistry learning?

2. Methodology

2.1. Research Design

Since the vocational school had different goals from high school, i.e., preparing the students to enter their careers right after graduation, thus their perception of the implementation of STEM learning should be investigated. To meet this issue, an explorative survey method was used. Using this method, this research concerns to explore HSCT and VSCT perceptions and knowledge toward STEM integration. Therefore, the profile and the comparison of the STEM knowledge between the two groups of teachers were revealed. The scheme on how this research was conducted seen in Figure 1.

Figure 1. Explorative Survey Method

2.2. Research Sample

Variable	High School		Vocational School	
	Frequency (f)	Proportion (%)	Frequency (f)	Proportion (%)
Sex				
Female	66	80.49	40	81.63
Male	16	19.51	9	18.37
Chemistry Teachers' Teaching Experience				
< 1 year	6	7.32	3	6.12
1-10 years	15	18.29	6	12.24
11-20 years	29	35.37	21	42.86
>20 years	32	39.02	19	38.78
Teaching for Grade				
X, XI, and XII	13	15.85	-	-
XI and XII	15	18.29	-	-
X and XII	7	8.54	-	-
X and XI	12	14.64	-	-
XII	13	15.85	-	-
XI	9	10.98	9	18.37
X	13	15.85	40	81.63

Table 1. Demographic features of the research sample

The research sample was established from two regencies in Yogyakarta, Indonesia, following a saturated sampling technique. This technique was employed because every in-service chemistry teacher in these two regencies took part in the data-gathering procedure. Unfortunately, only 82 HSCT and 49 VSCT returned the completed instrument and voluntarily agreed to be part of this research. The research samples were multiple in gender, age, teaching experience, and teaching grade (look at Table 1 for the demographic features of the research sample). However, they came from similar educational degrees and socio-economic backgrounds and came from low to middle-income families. Furthermore, as an ethical consideration, the research activities began after the researcher was given legal permission that the schools in these two regencies had accepted.

2.3. Data Collection Tools and Research Instruments

Perception Scale on STEM (PC-STEM) consisting of 54 closed-ended items and seven open-ended questions were used as the data collection tools. These 54 closed-ended items of PC-STEM were distributed into four sub-dimensions, namely the STEM basic concept, the requirement for STEM learning, the STEM integration, and the components in implementing STEM. The four sub-dimensions follow relevant works of literature, i.e., Shahali and Halim, 2015; El-Deghaidy, & Mansour, 2015; Kennedy, 2014; Ariani, Sudarmin & Nurhayat, 2019; Stohlmann, Moore & Roehrig, 2012 (Table 2 summarises the number and examples of closed-ended PC-STEM items with its sub-dimension that were tested in this research).

Sub-Dimension	Indicator	Number of Items	Example of Item
Basic concept of STEM	The relationship of STEM with everyday issues	5	STEM approach could be used in chemistry learning to solve everyday problems
	STEM learning facilitates a student-centred learning paradigm	4	The teacher plays a facilitator in the chemistry-based STEM learning
	The teachers' readiness to apply the STEM approach	5	To enhance their capacity to adopt the STEM approach, chemistry teachers need to be proficient in project-based learning design.
	The use of the STEM approach to develop holistic thinking skills	2	The STEM approach that enables PBL presents contextual issues; thus, it attracts students' willingness to learn chemistry
	The STEM approach provides positive learning outcomes	3	Students can innovate as a result of the use of the STEM approach.
	The need for STEM literacy in the chemistry learning	4	The teachers need to add more chemistry content to integrate STEM
The need for STEM learning	The STEM approach fulfils 21st-century learning requirement	7	The STEM approach could prepare the students to face global movement
	The STEM approach fulfils the need for student-centred learning	3	Through problem-based learning, the STEM approach illustrates everyday problems
The integration of STEM	A good instructional design that follows the STEM methodology	5	Project based learning is an alternate educational strategy to using STEM.
	The inter-correlation of the four disciplines in the STEM	5	The STEM approach could be applied by relating two disciplines, that is, science and mathematics
	Appropriate chemistry content to integrate the STEM approach	4	Most chemistry content could be implemented using the STEM approach
	Collaboration, communication, critical thinking, and creativity skills are improved by the STEM approach.	4	The STEM-based PBL offers pupils a chance to develop their critical thinking abilities.
The components of STEM implementation	Supporting elements for implementing STEM	8	The success of STEM implementation is caused by the appropriateness of the learning strategy
	Obstacles in applying the STEM approach	4	The lack of teachers' STEM literacy makes the implementation of STEM is not optimal

Table 2. Summary of number and example of items of closed-ended questions on PC-STEM

There were 34 positive and 20 negative statements that included in the 54 closed-ended questions of the PC-STEM on a 4-point Likert-type scale from strongly agree to strongly disagree. For positive items, the strongly agree score of 4, while the strongly disagree signified score of 1. On the other hand, for negative items, score 4 expressed strong disagreement, and score 1 showed strong agreement. Therefore, the maximum and minimum ideal scores that the teachers could obtain were 216 and 54, respectively. In addition, the open-ended part of PC-STEM includes seven open-ended questions. See Table 3 for the details of open-ended items in PC-STEM. These items aim to find out the prior knowledge of HSCT and VSCT related to STEM, which includes basic knowledge about the STEM approach, materials that can be used to apply the STEM approach, implementation of the STEM approach examples, and the weaknesses and strengths of applying the STEM approach.

A team of STEM professionals validated the PC-STEM before it was utilised to gather the data. They gave feedback towards PC-STEM regarding the face and content of the items, e.g., adding more specific sentences and terms used in the chemistry learning. The feedback from the experts was summed up and discussed with the researcher. A necessary revision was made following the agreement of the researcher. Furthermore, to ensure empirical validity, the closed-ended items of PC-STEM were tested through a pilot study towards HSCT and VSCT outside the research sample. The reliability analysis signified a 0.967 Cronbach Alpha value. This value indicates that the PC-STEM is a valid and reliable instrument for collecting chemistry teachers' perceptions toward STEM. Therefore, the recent version of PC-STEM was administered through paper and pencil tests in the research sample. They were given 60 minutes to fill out the PC-STEM instrument. Before they responded to PC-STEM, the research samples were told that their perception in responding to the PC-STEM would not affect their performances. Thus, they need to answer all of the items in the PC-STEM honestly from their point of view. Moreover, to ensure confidentiality, the research sample name was written anonymously.

No.	Question
Q1.	Have you come across the word STEM before? If so, how did you hear about it?
Q2.	Explain what do you know about STEM learning!
Q3.	Do you think the STEM approach can be used in chemistry learning? Give an illustration of its use!
Q4.	What types of chemistry materials are appropriate for using the STEM learning? Give an illustration!
Q5.	Do you have any experience teaching chemistry using the STEM approach? Explain!
Q6.	What are the drawbacks of using the STEM approach in chemistry classes?
Q7.	What benefits do STEM initiatives have when used in chemistry classes?

Table 3. Open-Ended Part of PC-STEM

2.4. Data Analysis

To address the research questions, a content analysis with interpretive coding, descriptive statistics, and a one-way MANOVA test were used. The goal of the content analysis with interpretive coding as a qualitative study is to examine the background information that chemistry teachers in high school and vocational high school have learned about STEM integration through PC-STEM. According to Huberman and Miles (2005), the tasks involved in qualitative data analysis should be carried out repeatedly until they are finished. Data reduction, data visualisation, and conclusion drawing/verification are the stages in data analysis. Data transcription, coding, and re-coding are the three processes that make up the data reduction process.

Descriptive statistics were performed in order to analyse the level of the perceptions of HCT and VSCT towards STEM. The final mean score on each research sample was categorized into four criteria ranging from excellent to poor, adapting to Gronlund and Linn (1990). The frequency of each category was calculated and then converted into percentages. Furthermore, in order to analyse the significant differences between HSCT and VSCT perceptions toward STEM, the one-way MANOVA test was executed.

3. Findings

This section explains the findings of this study. Table 4 displays the descriptive statistics of the research sample's perceptions. Based on Table 4, overall, the perceptions of HSCT towards STEM are more positive than the perceptions of VSCT. In comparison to VSCT, the perspectives of HSCT regarding the fundamentals of STEM, the need for STEM education, the integration of STEM, and factors in implementing STEM are superior. Additionally, the outcomes of this study were presented after the research questions in order to allow for a deeper examination of the conclusions.

3.1. Research Question 1: What Initial Knowledge do High School and Vocational High School Chemistry Teachers Have Regarding the Use of an Integrated STEM Approach in Chemistry Learning?

In this study, responses to open-ended questions made up of seven PC-STEM questions were assessed to determine the chemistry teacher's initial understanding of an integrated STEM approach. There were seven themes for seven questions since the responses of the respondents were classified according to the number of questions.

Group	Parameter	Overall	Dimensions of STEM Perception			
			Basic concept of STEM	Need of STEM learning	Integration of STEM	Components in implementing STEM
HSCT	No of samples	82	82	82	82	82
	Mean	175.56	65.39	33.17	47.26	29.74
	SD	15.99	6.39	3.65	3.83	3.08
	Highest Score	210	80	40	59	36
	Lowest Score	154	56	28	40	26
VSCT	No of samples	49	49	49	49	49
	Mean	172.18	64.45	32.39	46.12	29.22
	SD	14.23	5.31	3.36	4.15	2.76
	Highest Score	213	77	40	60	36
	Lowest Score	155	58	28	40	26

Table 4. Descriptive Statistics of the Research

3.1.1. Source of Knowledge about STEM

The first question is, *"Have you come across the word STEM before? If so, how did you hear about it?"* Have you ever heard of STEM? is the first query. If so, how did you hear about it? According to participant responses to this question, 98.47% of participants said they had heard the phrase STEM, while the remaining participants said they had never even heard of it. Therefore, the majority of the chemistry teachers in our survey are familiar with the phrase STEM. Table 5 displays the outcomes of data reduction in relation to the responses to these queries.

Codes	f		%	
	HSCT	VSCT	HSCT	VSCT
Training on STEM	10	11	12.50	22.45
Seminar	2	1	2.50	2.04
Internet, journals, books	10	8	12.50	16.33
Friends	13	10	16.25	29.41
Workshop dan technical guidance	30	16	37.50	32.65
n/A	8	3	10.00	6.12

Table 5. Source of Knowledge about STEM

Considering the information in Table 5, the majority of in-service teachers (37.50% of the total HSCT and 32.65% of the total VSCT) are already familiar with the term STEM because of workshops and technological support. The majority of these events take place at the Indonesian city of Yogyakarta's Chemistry Teacher Association, or "MGMP." The organising committee took advantage of this chance to improve the skills of chemistry teachers working in STEM-related roles.

3.1.2. Understanding an Integrated STEM Learning

The question "*What do you know about STEM?"* was posed after the majority of participants indicated that they had heard the term STEM. Participants who acknowledged hearing the term STEM provided the answers to these questions. As stated in Table 6, the conclusions in relation to this subject are divided into nine categories.

The data in Table 6 reveal that the majority of chemistry teachers believe that STEM is a learning activity that combines science, technology, engineering, and mathematics (which is stated by 77% and 77.5% of the total chemistry teachers participating in high school and vocational school, respectively). Another comment from in-service chemistry teachers hinted that the STEM approach is a learning strategy to handle challenges of daily life, learning that serves to improve the learning skills of 21st-century students, student-centred learning, etc.

Codes	f		%	
	HSCT	**VSCT**	**HSCT**	**VSCT**
Modern learning by using technology and producing products	6	3	7.50	6.12
Learning approach to solving everyday problems	9	1	11.25	2.04
Learning instruction that develops 21st century skills	3	2	3.75	4.08
Learning that integrates Science, Technology, Engineering and Mathematics	56	28	70.00	77.55
Learning approaches	2	2	2.50	4.08
n/A	4	3	5.00	6.12

Table 6. The Definition of STEM Learning

3.1.3. Opinions on the Use of Integrated STEM in Chemistry Education

The next open question is, *"Do you think the STEM approach can be used in chemistry learning? Give an illustration of its use!"*. The purpose of this inquiry is to understand more about the chemistry teacher's perspective on incorporating STEM into chemistry instruction. Table 7 gives a brief overview of the findings of the coding procedure for examples of STEM integration in chemistry classrooms.

Table 7 provides instances of how STEM is applied in chemistry learning based on HSCT and VSCT opinions. According to respondents, the most well-liked ways to incorporate STEM into chemistry instruction for both high school and vocational high school chemistry teachers are to make ice cream using the concept of freezing point depression and to make lamps using fruit as an energy source based on the concept of electrolyte and non-electrolyte solutions. Furthermore, HSCT and VSCT have the option of incorporating STEM into chemistry learning activities by using mangosteen peel to make ice cream that acts as an antioxidant by applying the idea of freezing point depression to the colloidal characteristics of solutions.

Codes	f		%	
	HSCT	VSCT	HSCT	VSCT
Using the idea of the of colligative properties of solutions to make ice cream	4	4	18.18	8.16
Constructing rockets using the theory of chemical reactions	1	-	4.54	-
Making tools for measuring soil pH and water quality	2	-	9.09	-
Management of plastic and polymer waste	2	2	9.09	4.08
Use of RAR on electron configuration materials	1	-	4.54	-
Processing used cooking oil waste into laundry soap	2	3	9.09	6.12
Scan the QR code for nomenclature material with memes	1	-	4.54	-
Lamp with energy source from fruit based on the concept of electrolyte and voltaic cell	3	-	13.64	-
Making prototypes on polymer materials	1	-	4.54	-
Using the colloid idea to make jam	1	-	4.54	-
Using the principle of coagulation to purify water.	2	3	9.09	6.12
Explanation of the electric shock phenomenon	1	-	4.54	-
Constructing a basic distillation tool	1	-	4.54	-
Electrolysis on metal plating	-	8	-	16.33
Innovation of natural indicators of natural ingredients based on the concept of acid-base	-	4	-	8.16
Create a fuel-saver tool	-	2	-	4.08

Table 7. Application of Integrated STEM in Chemistry Learning

3.1.4. Suitable Chemistry Concept for Integrated STEM Learning

"What chemistry concept is appropriate for using the STEM approach?" was the question posed to the chemistry teacher in this sub-dimension. Because each participant could express their opinion on multiple types of chemistry appropriate for STEM applications, the number of participants was exceeded by the number of responses to this question from participants. Table 8 presents the results in relation to this query.

Codes	f		%	
	HSCT	VSCT	HSCT	VSCT
Redox and electrochemistry	27	29	25.00	40.84
Chemical Bonding	2	4	1.85	5.63
Hydrocarbon	9	4	8.33	5.63
Acid and Base	11	8	10.18	11.27
Stoichiometry	4	7	3.70	9.86
Colligative properties of solutions	12	1	11.11	1.41
Polymerization	3	3	2.78	4.23
Colloid	6	5	5.56	7.04
Reaction rate	7	3	6.48	4.23
Chemical nomenclature	1	-	0.93	-
Chemical equilibrium	7	-	6.48	-
Thermochemistry	5	2	4.63	2.82
Electrolyte & non-electrolyte solutions	11	1	10.18	1.41
Petroleum	2	-	1.85	-
n/A	1	4	0.93	5.63

Table 8. Suitable Materials Using the STEM Approach

Topics that can be used to implement the STEM approach in learning chemistry are listed in Table 8. The majority of the chemistry teachers who participated in this survey said that the ideas of redox and electrochemical reactions were very complementary to the STEM approach.

3.1.5. Teacher's Experiences in Applying an Integrated STEM Approach

Have you ever used an Integrated STEM approach in chemistry learning? is another question that inquiries about the experience of chemistry teachers in using the STEM approach. The answer reveals that just a small percentage of teachers have included STEM in chemistry learning activities. In-service chemistry teachers (46% of HSCT and 31% of VSCT) who have adopted STEM learning make up no more than half of the participants. It is indicated that chemistry teachers who are now in the classroom still lack experience incorporating STEM. Participants who have incorporated STEM describe about their experiences while studying chemistry. Table 9 displays some participants' reactions to their experiences incorporating STEM.

Looking at the data in Table 9, the participants gave some excellent instances of how they have incorporated STEM into their study of chemistry. The participants discussed how to use STEM to tackle common issues, such as creating antioxidant ice cream from mangosteen peel using the idea of colloidal and stoichiometric ideas as well as the colligative properties of solutions. However, the modest number of participants who included STEM-based chemistry education suggested that teachers were not as supportive of STEM implementation.

Participants	Chemistry Teachers	Experiences
Participant 4	HSCT	Yes, what has been done for chemical reactions (rockets), petroleum (biodiesel), acid-base (manufacture of food products)
Participant 7	HSCT	Once. Introduction to Chemistry. Chemistry in life, for example, making soap and hand sanitiser
Participant 10	HSCT	Once. That is by applying it to make healthy ice cream with colloidal material.
Participant 17	HSCT	Yes, you can make ice cream with natural ingredients with colligative properties concept
Participant 33	HSCT	Once, on the material of molecular shape by making a night lamp with a molecular shape design and on the material of chemical nomenclature by making a Q.R. Code.
Participant 49	HSCT	Once, students were asked to design and manufacture an electrolyte test kit and test it on seawater at Parangtritis beach
Participant 50	HSCT	Ever, on acid-base materials by making natural indicators
Participant 76	HSCT	Once, students were asked to design tools and methods for water purification
Participant 48	HSCT	Yes, by making distillation equipment, gilding equipment and making ice cream
Participant 81	HSCT	Made a design for processing plastic waste into fuel
Participant 83	VSCT	Once, K.D 3.9 electrochemistry, namely the sub-material of electrolysis, namely electroplating
Participant 100	VSCT	Ever, in the electrical conductivity test material using natural materials
Participant 111	VSCT	Students were required to build their own test kits and test electrolyte and non-electrolyte solutions as part of their study of electrolytes and non-electrolytes.

Table 9. Teacher's Experience in Applying an Integrated STEM Approach

3.1.6. Drawbacks of an Integrated STEM Approach

The following query sought participants' perspectives on the drawbacks of STEM integration in chemistry education. "*What are the weaknesses of the implementation of STEM approach in chemistry learning?*" is the issue posed. As indicated in Table 10, the replies of the participants were divided into seven groups.

Codes	f		%	
	HSCT	VSCT	HSCT	VSCT
Limited to certain materials or basic competencies	14	5	17.07	9.43
Requires a relatively long learning time	33	7	40.24	13.21
Requires complete facilities and infrastructure	7	10	8.54	18.87
Influenced by students' abilities	8	5	9.76	9.43
Requires good teacher skills	10	18	12.20	33.96
Limited tools, materials and costs	3	2	3.66	3.77
Don't know	5	6	6.09	11.32
n/A	2	-	2.44	-

Table 10. Disadvantages of an Integrated STEM Approach

The limitations of the STEM approach in chemistry learning are shown in the tiny number of participants who have not used it. After analysing the data in Table 10, the majority of the in-service chemistry teachers admitted that they required more time to adopt STEM teaching and that they lacked the necessary abilities to incorporate their STEM-based learning. Additionally, according to HSCT and VSCT, the fundamental issue with integrating STEM was that not all chemistry materials could be used to do so. This has ramifications for their ignorance of real-world instances when the STEM approach has been used to teach chemistry.

3.1.7. Benefits of an Integrated STEM Approach

Participants discussed the benefits of the STEM approach in chemistry learning in addition to its disadvantages. The final question, "*What are the advantages of the STEM approach if applied in the chemistry class?*", is intended to examine the chemistry teacher's perspective on the benefits of STEM learning. Table 11 summarises the findings in response to this query by constructing the following eight groups of topics.

According to participant responses summarised in Table 11, the majority of in-service chemistry teachers concur that STEM can help students grasp their lessons and make connections between them and real-world situations.

Codes	f		%	
	HSCT	VSCT	HSCT	HSCT
Improve 4C (Critical Thinking, Communication, Creativity, Collaboration) skills	21	14	25.61	26.92
Improve understanding of the material and its application in life	33	8	40.24	15.38
Learning is more interesting, motivating and not monotonous	14	16	17.07	30.77
Making teachers creative in designing learning	2	2	2.44	3.85
Increase student involvement because STEM is student-based learning	6	4	7.32	7.69
In line with the growth of 21st-century learning	1	-	1.22	-
Produce a prototype or a product	1	3	1.22	5.77
Utilizing materials around students	1	-	1.22	-
n/A	3	5	3.66	9.62

Table 11. Advantages of an Integrated STEM Approach

3.2. Research Question 2: What Is the Level of the Chemistry Teachers' Perspectives Regarding Employing an Integrated STEM Approach to Chemistry Instruction in High School and Vocational High School?

The findings of the level of HSCTs' and VSCTs' perspectives in applying an integrated STEM approach in chemistry learning with each factor on it are presented in Table 12. As can be seen in Table 4, it was clear that either HSCT or VSCT showed an excellent perspective toward integrated STEM learning in chemistry lessons. This finding is supported by HSCT and VSCT perspectives on each dimension of STEM perception. They have a good view of integrated STEM learning on each dimension of STEM perception (e.g., STEM fundamental concept, the need for STEM learning, integration of STEM learning, and components in implementing STEM).

3.3. Research Question 3: Are there Differences in the Perspectives of High School and Vocational High School Chemistry Teachers in Applying an Integrated STEM Approach to Chemistry Learning?

A statistical analysis was necessary to identify statistically significant differences between HSCT and VSCT, even if their opinions on the use of an integrated STEM approach in chemistry learning varied based on their mean scores. The outcomes of a one-way MANOVA test that looked into these variations are shown in Table 13. Table 13 shows that there is no difference in opinion between HSCT and VSCT about the use of STEM in learning chemistry, with a 95% confidence level. Likewise, there were no statistically significant differences across the integrated STEM perspectives' dimensions.

Dimensions of STEM Perception						
	Group	**Overall N item=54**	**Basic concept of STEM N item=20**	**Need for STEM learning N item=10**	**Integration of STEM N item=15**	**Components in implementing STEM N item=9**
Ideal score		216	80	40	60	36
Mean Score	HSCT	175.56	65.39	33.17	47.26	29.74
	VSCT	172.18	64.45	32.39	46.12	29.22
Level	HSCT	Good	Good	Good	Good	Good
	VSCT	Good	Good	Good	Good	Good
Percentage of teachers' view in each level category						
Interval		**Category**	**HSCT**		**VSCT**	
			Frequency	**Percentage**	**Frequency**	**Percentage**
x > 183.6		Excellent	49	59.76	28	57.14
151.2 > x ≥ 183.6		Good	33	40.24	21	42.86
118.8 > x ≥ 151.2		Fair	0	0	0	0
x ≤ 118.8		Poor	0	0	0	0

Table 12. The profile of HSCT and VSCT view toward STEM

Test	**Pillai's Trace**	**Test of Between Subject Effects**			
		Basic concept of STEM	**Need for STEM learning**	**Integration of STEM**	**Factors in implementing STEM**
F	0.805	0.753	1.498	2.526	0.943
P*	0.524	0.387	0.223	0.114	0.333
Partial Eta Squared	0.025	0.006	0.011	0.019	0.007
Conclusion*)	No Different	No Different	No Different	No Different	No Different

*Computed using alpha 0.05

Table 13. The significant differences among HSCT and VSCT views toward STEM

4. Discussion

4.1. The Initial Knowledge High School and Vocational High School Chemistry Teachers Have Regarding the Use of an Integrated STEM approach in Chemistry Learning

Through workshops and technical support, the HSCT and VSCT became familiar with the concept of integrated STEM (see Table 3). The majority of these events took place at the Indonesian city of Yogyakarta's Chemistry Teacher Association, also known as the "MGMP." The organizing committee took advantage of this chance to help chemistry teachers become more proficient in roles that use an integrated STEM approach. This demonstrates how the Indonesian government encourages chemistry teachers who want to incorporate STEM into their lessons. Additionally, professional development programs are created to promote cooperation among chemistry teachers who are currently in the classroom in order to integrate the STEM approach (Kelcey & Phelps, 2013). Through MGMP, teachers can share their expertise with others and bring fresh perspectives to the planning of chemistry lectures (Rismark & Slvberg, 2011). The findings of this study support earlier research by Nugroho, Permanasari and Firman (2019), which found that more than half of the MGMP teachers helped other teachers implement integrated STEM learning. In other words, HSCT and VSCT are familiar with the phrase STEM informally through their friends and other learning tools including the internet, journals, and textbooks, despite participating in official activities. This demonstrates their interest in how STEM is being incorporated into chemistry education. As a result, they look for STEM materials to understand everything they can about how STEM is interwoven into the study of chemistry.

Following their disclosure of the sources from which they learned the phrase "STEM," the notions of integrated STEM held by HSCT and VSCT were investigated. According to the HSCT and VSCT, integrated STEM refers to a learning approach that combines science, technology, engineering, and mathematics. Other responses from in-service chemistry teachers suggested that integrated STEM learning is an approach for tackling problems in daily life; some of them described integrated STEM learning as instructional learning to develop 21st-century student learning skills; some of them also asserted that integrated STEM learning is student-centered learning, etc. According to Kennedy (2014), integrated STEM is a learning that combines technology and engineering with science and mathematics through engineering process design and scientific inquiry. Accordingly, the integrated STEM approach is defined by Stohlman et al. (2012) as an effort to combine science, technology, engineering, and mathematics into a single, comprehensive body of knowledge. If the teacher is knowledgeable about numerous scientific fields and comprehends chemical concepts from a variety of scientific vantage points, STEM learning will be more effective (Ejiwale, 2012). Thus, the definition of STEM according to the chemistry teacher is largely accurate.

Nevertheless, due to their misrepresentation of the integrated STEM approach, roughly 5–6% of the participant's responses to the survey could not be classified. The participants defined STEM as a method of learning, a system of learning, and a model of learning. Although few, it is still possible to conceptually shift by increasing in-service chemistry teachers' understanding of integrated STEM through a variety of sources. A teachers' professional development program in integrated STEM is required in this situation.

In-service chemistry teachers' perspectives on examples of integrated STEM application in chemistry learning were the area of further investigation. According to the participants, when it came time to include STEM into chemistry courses, manufacturing ice cream with the notion of freezing point depression, making lamps utilizing fruits as an electrolyte-based energy source, and the concept of the non-electrolyte solution were the most well-liked ideas. Teachers must connect chemistry material to commonplace phenomena while incorporating the STEM approach into chemistry education. As a result, the link of learning chemistry to daily life will be made clear, which can boost students' interest in the subject, their level of chemical literacy, and their attitudes towards science (Holbrook & Rannikmae, 2007; Wiyarsi et al., 2020; Cepni, Ulger & Ormanci, 2017; Calik & Cobern, 2017).

The chemistry teachers must examine proper chemistry content, they could plan utilizations of the integrated STEM approach well. That is, they must ensure that the topics designed can be integrated into four disciplines (Devi, Karyana & Nulhakim, 2018). The majority of HSCT and VSCT in this study claimed that the integrated STEM approach was very compatible with chemistry's ideas about redox and electrochemical reactions. They gave instances of making batteries using fruits under the concept of redox reactions and voltaic cells. As part of the Science component, the concept of redox reaction and voltaic cells is used to determine which fruits are appropriate in order to make the battery work and turn on the bulb. The idea of how the fruit battery could be used to ease people's lives is part of the Technology component. The design of the fruit battery that could be arranged in the form of a series or parallel circuit to produce the lightest bulbs belongs to the Engineering component. Meanwhile, calculating the number of currents that could be measured from the fruit battery could be investigated under the Mathematics component.

Another example that was revealed was the production of an extract of mangosteen peel as an antioxidant ice cream in the form of colligative properties of solution. The concept of freezing point depression is used to describe how the temperature of the solution could be lower in producing ice cream as a Science component. Presenting the tools kit to make the ice cream belongs to the Technology component. In the component of Engineering component, the students could try out the design of the tools to make the mangosteen peel ice cream and when the results are not as expected then the latest design must be re-designed and tested again. The calculation of the amount of mangosteen peel and the freezing point depression were included in the Mathematics component.

Different examples of the phenomena of electroplating that explain the ideas of electrolysis, electroplating, and Faraday's law belong to the Science component. Presenting devices, electrodes, solutions, and current sources that are included in the Technology component could be explained in this case. The design of metal coating processes with a certain layer area and thickness is under the purview of the Engineering component. The phenomena of electroplating are connected to estimating the quantity of metal needed to coat metal with a specific layer thickness could be explored in the component of Mathematics. Therefore, before integrating STEM learning into chemistry instruction, either HSCT or VSCT must examine the content of chemistry subjects encompassing the four STEM categories.

Phrased differently, the participants provided fantastic examples of their experiences incorporating STEM. The participants discussed how to use STEM to tackle common issues, such as creating antioxidant ice cream from mangosteen peel utilizing the idea of colloidal and stoichiometric ideas as well as the colligative properties of solutions. The use of the STEM approach to the study of chemistry makes the educational setting engaging. However, a large number of participants still lack basic knowledge and expertise in integrating STEM. They must thus develop their skills in order to be ready to learn chemistry utilizing STEM using any available resources.

The shortcoming of the STEM approach in chemistry learning is attributed to the limited percentage of participants who have not used the integrated STEM approach. According to the data in Table 8, the majority of HSCT and VSCT programs needed more time to integrate STEM. This challenge is consistent with research by Sheffield, Koul, Blackley, Fitriani, Rahmawati and Resek (2018), which demonstrates that the applied curriculum, time constraints, and teacher competency all contribute to the STEM approach's shortcomings. To enhance instructors' capacity to oversee STEM instruction, pedagogical competency is required. When adopting integrated STEM as a teaching strategy, teachers must be imaginative, open to diverse viewpoints, and logical in their thinking (Asghar, Ellington, Rice, Johnson & Prime, 2012). Another challenge that the participants ran across was the fact that not all chemistry lessons could be taught utilizing the STEM approach. They claimed that creating a chemistry lecture on a specific chemical topic is challenging. Chemistry teachers look at a number of criteria, such as material that emphasizes context, practice, answers, issues, and product creation, to identify chemical principles that may be used with STEM (Fitriyana, Wiyarsi, Pratomo, Marfuatun, Krisdiyanti & Adilaregina, 2021).

In addition, the results of participants' views on STEM integration shown in Table 9 reveal that the majority of HSCT and VSCT concur that STEM may enhance students' comprehension and associate chemistry with daily life. According to Basha (2018), STEM also helps students become more proficient in 21st-century learning abilities including cooperation, communication, and critical thinking. According to Roberts, Jackson, Mohr-Schroeder, Bush, Maiorca, Cavalcanti et al. (2018), the STEM approach encourages students to have fresh experiences that help them better grasp STEM subjects and pique their interest in chemistry. Few participants overall claimed to be unaware of the advantages of STEM integration. This figure may have an impact on participants' understanding of the advantages of incorporating STEM into their chemistry education in order to attain meaningful chemistry learning.

4.2. The Level of the Chemistry Teachers' Perspectives Regarding Employing an Integrated STEM Approach to Chemistry Instruction in High School and Vocational High School

The perspectives of HSCT and VSCT on the application of integrated STEM approach, according to Table 12, revealed that the majority of HSCT and VSCT have good perceptions. Regarding the basic concept of STEM, most high school and vocational high school chemistry teachers agreed that the STEM approach could be implemented in learning chemistry to solve real-world problems. This statement follows the theory that STEM learning encourages students to solve and implement problems in everyday life (Ejiwale, 2012). In the statement "the STEM approach integration could encourage students to make innovation," most respondents agreed that according to the integrated chemistry learning theory, STEM in chemistry triggers students to innovate and to enhance learning outcomes for students at high school.

In the second aspect regarding the need for STEM learning, the statement "the STEM approach can prepare students to face global economic changes" resulted in most high school and vocational high school chemistry teachers agreeing with this statement. This statement is supported by the idea that STEM learning is a worldwide discussion in the 21st century to face global economic changes and prepare a quality workforce (Kennedy, 2014).

The third aspect of the perception scale contains statements about STEM integration. In the statement "STEM approach through PBL model that can encourage students' critical thinking skills", most HSCT and VSCT agreed. These results are supported by the theory of learning strategies that can be done, namely by applying the Project-based-Learning (PjBL) as well as Problem-based-Learning (PBL) models (Siregar, Rahmawati & Suyono, 2023; Ananda, Rahmawati & Khairi, 2023). This learning model can improve collaboration skills, develop interdisciplinary ideas, and experience learning using technology (Kennedy, 2014).

The components for applying STEM are the fourth factor evaluated on the perceptual scale. The effectiveness of applying the STEM approach supported by suitable learning techniques and producing results on which most HSCT and VSCT agree is one of the assertions to measure the implementation supporting components. Teacher-designed learning designs, teacher support for what students do, and changing the learning environment are three important elements that affect the implementation of integrated STEM learning (Shernoff, Sinha, Bressler & Ginsburg, 2017).

Individuals' perceptions can vary from one another; for instance, different people respond differently to particular signs. The responses from HSCT and VSCT are typically backed by ideas and claims made in earlier studies. Most HSCT and VSCT have positive impressions of using the integrated STEM approach to teach chemistry, according to the categorization findings. Before integrating the STEM approach into teaching chemistry and fundamental knowledge, instructors of chemistry must first have a favorable opinion of the STEM approach in order for it to be successful. Let's assume the instructor has a positive understanding of how to use the STEM method. In that circumstance, it is anticipated that the teachers can effectively use STEM. The teacher's perception before learning enables them to feel more confident about the aspects of planning, execution, and assessment after the learning program. According to Altan and Ercan (2016), this may be the outcome of instructors actively participating in several STEM-related activities.

4.3. Differences in the Perspectives of High School and Vocational High School Chemistry Teachers in Applying an Integrated STEM Approach to Chemistry Learning

There is not a significant distinction between the HSCT and VSCT viewpoints on integrated STEM, according to the findings of the one-way MANOVA test analysis. HSCT had a higher average perception score than VSCT despite the fact that there was no significant difference. This is due to the fact that HSCTs engage in teacher professional development programs more actively than VSCTs. The data on the chemistry teacher's initial understanding of sources of information on integrated STEM through chemistry MGMP, training, workshops, and technical assistance may be used to observe the professional growth of teachers who have undergone HSCT. While this was going on, VSCT only received technical advice and training about integrated STEM.

As opposed to chemistry education in high school, vocational school chemistry instruction prioritizes skills. The STEM approach, which prioritizes skills, is consistent with how chemistry is taught in vocational schools. In order to prepare students for a career with 21st-century abilities, learning using an integrated STEM approach focuses on the competencies of each STEM field (Honey, Pearson & Schweingruber, 2014; Altan & Ercan, 2016). Consequently, there is a connection between the integrated STEM approach and chemistry education in vocational schools. Different aspects are revealed by the findings of teachers' perceptions of how the integrated STEM approach is used. The opinions of HSCT and VSCT are seen similarly, with no significant differences. This could be due to their inexperience in integrating STEM concepts into chemistry education.

School instructors are encouraged to collaborate through professional development programs (Kelcey & Phelps, 2013). The quality of teachers may be raised through professional development, such as government-sponsored training and seminars on using an integrated STEM approach (Nugroho et al., 2019). To assist them in grasping STEM pedagogy and acquiring an in-depth understanding of STEM material, teachers must take part in professional development opportunities (Nadelson, McGuire, Davis, Farid, Hardy, Hsu et al., 2017). After taking part in the teaching profession program, teachers' attitudes toward using the STEM approach increased (El-Deghaidy & Mansour, 2015).

On the other hand, situational and personal factors influence perception. Needs, prior experiences, and other things that are part of functional factors are where functional factors originate. Therefore, the features of the individual who responds to the stimulus, rather than the type or shape of the stimulus, determine perception (Endararia, 2015). The STEM approach to teaching can be used differently in vocational and secondary schools due to variations in the curricula and chemical content, although these variances are not certain to affect students' perspectives. The chemical teacher's workplace or location of instruction is an outside variable. However, the viewpoint, attitude, and expertise of the individual or teachers are the key determinants of perception (Akaygun & Aslan-Tutak, 2016).

5. Conclusions

The initial knowledge of most of HSCT and VSCT in applying an integrated STEM approach is good. However, they showed a lack of knowledge in giving an example of applying the integrated STEM approach to chemistry due to their limited experiences in dealing with integrated STEM learning in chemistry. A few teachers are still unsure whether integrated STEM can be applied to chemistry learning, so they need to increase their knowledge about applying the STEM approach through professional development programs (e.g., training, workshops, or reading journals). Although both HSCT and VSCT signified good perspectives toward integrated STEM learning in chemistry lessons, which means that integrated STEM learning is an important pedagogy to achieve meaningful chemistry learning, however; no significant difference was identified in the perception of HSCT and VSCT about this integrated STEM learning. Therefore, future studies must explore the benefits of an integrated STEM approach for students' transferable skills in chemistry classrooms either in high school or vocational school.

Declaration of Conflicting Interests

The chemistry teachers where the data was collected had given their consent before the research could begin. The students who took part in the study voluntarily provided the data, and the researcher will keep the participants' identities secret. The authors declare that there are no potential conflicts of interest in this study.

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References

Akaygun, S., & Aslan-Tutak, F. (2016). STEM images revealing STEM conceptions of pre-service chemistry and mathematics teachers. *International Journal of Education in Mathematics, Science and Technology,* 4(1), 56-71. https://doi.org/10.18404/ijemst.44833

Altan, E.B., & Ercan, S. (2016). STEM Education Program for Science Teachers: Perceptions and Competencies. *Journal of Turkish Science Education,* 13, 103-117.

Ananda, L.R., Rahmawati, Y., & Khairi, F. (2023). Critical thinking skills of chemistry students by integrating design thinking with STEAM-PJBL. *Journal of Technology and Science Education,* 13(1), 352-367. https://doi.org/10.3926/jotse.1938

Ariani, L., Sudarmin, & Nurhayat, S. (2019). Analisis berpikir kreatif pada penerapan problem-based learning berpendekatan Science, Technology, Engineeering and Mathematics. *Jurnal Inovasi Pendidikan Kimia,* 13(1), 2307-2317. Available at: https://journal.unnes.ac.id/nju/index.php/JIPK/article/view/15159

Asghar, A., Ellington, R., Rice, E., Johnson, F., & Prime, G.M. (2012). Supporting STEM education in secondary science contexts. *Interdisciplinary Journal of Problem-Based Learning,* 6(2), 85-125. https://doi.org/10.7771/1541-5015.1349

Aydin-Gunbatar, S., Tarkin-Celikkiran, A., Kutucu, E.S., & Ekiz-Kiran, B. (2018). The influence of a design-based STEM education. *Chemistry Education Research and Practice,* 19(3), 954-972. https://doi.org/10.1039/c8rp00128f

Aydin-Gunbatar, S., Ekiz-Kiran, B., & Oztay, E.S. (2020). Pre-service chemistry teachers' pedagogical content knowledge for integrated stem development with LESMeR model. *Chemistry Education Research and Practice,* 21(4), 1063-1082. https://doi.org/10.1039/D0RP00074D

Basha, H.A. (2018) *Investigating teachers' perceptions and implementation of STEM education in the United Arab Emirate.* Dissertation. UAE: The British University in Dubai.

Breiner, J.M., Harkness, S.S., Johnson, C.C., & Koehler, C.M. (2012). What is STEM? A discussion about conceptions of stem in education and partnerships. *School Science and Mathematics,* 112(1), 3-11. https://doi.org/10.1111/j.1949-8594.2011.00109.x

Bryan, L.A., Moore, T.J., Johnson, C.C., & Roehrig, G.H. (2015). Integrated STEM education. In Johnson, C.C., Peters-Burton, E.E., & Moore T.J. (Eds.), *STEM road map: A framework for integrated STEM education* (23-37). New York: Routledge. https://doi.org/10.4324/9781315753157-3

Bullock, E. (2017). Only STEM can save us? Examining race, place, and STEM education as property. *Educational Studies,* 53(6), 628-641. https://doi.org/10.1080/00131946.2017.1369082

Çalık, M., & Cobern, W.W. (2017). A cross-cultural study of CKCM efficacy in an undergraduate chemistry classroom. *Chemistry Education Research and Practice,* 18(4), 691-709. https://doi.org/10.1039/c7rp00016b

Cepni, S., Ulger, B.B., & Ormanci, U., (2017). Pre-service science teachers' views towards the process of associating science concepts with everyday life. *Journal of Turkish Science Education,* 14(4), 1-15. https://doi.org/10.12973/tused.10208a

Chachashvili-Bolotin, S., Milner-Bolotin, M., & Lissitsa, S. (2016). Examination of factors predicting secondary students' interest in tertiary STEM education. *International Journal of Science Education,* 38(3), 366-390. https://doi.org/10.1080/09500693.2016.1143137

Chonkaew, P., Sukhummek, B., & Faikhamta, C. (2016). Development of analytical thinking ability and attitudes towards science learning of grade-11 students through science technology engineering and mathematics (STEM education) in the study of stoichiometry. *Chemistry Education Research and Practice,* 17(4), 842-861. https://doi.org/10.1039/c6rp00074f

Craig, C.J., Verma, R., Stokes, D., Evans, P., & Abrol, B. (2018). The influence of parents on undergraduate and graduate students' entering the STEM disciplines and STEM careers. *International Journal of Science Education,* 40(6), 621-643. https://doi.org/10.1080/09500693.2018.1431853

Devi, P.K., Karyana, S., & Nulhakim, L. (2018). *Elektrokimia: Electroplating/pelapisan logam*. South East Asia Ministry of Education Organization (SEAMEO QIETP) In Science.

Du, W., Liu, D., Johnson, C.C., Sondergeld, T.A., Bolshakova, V.L.J., & Moore, T.J. (2019). The impact of integrated STEM professional development on teacher quality. *School Science and Mathematics,* 119(2), 105-114. https://doi.org/10.1111/ssm.12318

Ejiwale, J. (2012). Facilitating teaching and learning across STEM fields. *Journal of STEM Education,* 13(3), 177. https://doi.org/10.11591/edulearn.v6i3.161

El-Deghaidy & Mansour (2015). Science teachers' perceptions of STEM education: Possibilities and challenges. *International Journal of Learning and Teaching,* 1(1), 51-54. https://doi.org/10.18178/IJLT.1.1.51-54

Endararia (2015). Influence perception accounting students against ethics preparation of financial reporting. *Research Journal of Finance and Accounting,* 6(6), 104-111.

Febrianto, Wiyarsi, A., Partana, C.F., & Sulistyo, B. (2019). Chemistry in context: The development of hydrocarbon chemistry and petroleum module based on vehicle case. *IOP Conf. Series: Journal of Physics: Conference Series,* 1156, 1-8. https://doi.org/10.1088/1742-6596/1156/1/012021

Fitriyana, N., Wiyarsi, A., Pratomo, H., Marfuatun, Krisdiyanti, A., & Adilaregina, W. (2021). In-service chemistry teachers' prior knowledge regarding STEM integration in high school chemistry learning. *Advances in Social Science, Education, and Humanities Research,* 528, 218-230. https://doi.org/10.2991/assehr.k.210305.033

Fitriyana, N., Pratomo, H., Wiyarsi, A., & Marfuatun (2023). In-service high school chemistry teachers' view towards chemistry: Is it a difficult subject? *AIP Conference Proceedings,* 2556, 040016. https://doi.org/10.1063/5.0109916

Franz-Odendaal, T.A., Blotnicky, K., French, F., & Joy, P. (2016). Experiences and perceptions of STEM subjects, careers, and engagement in STEM activities among middle school students in the Maritime Provinces. *Canadian Journal of Science, Mathematics and Technology Education,* 16(2), 153-168. https://doi.org/10.1080/14926156.2016.1166291

Ghalkhani, M., & Esmaeili, K. (2022). Designing an educational content for corrosion based on STEM approach for undergraduate chemistry level. *The Quarterly Journal of Research in Chemistry Education,* 3(4), 45-70.

Gronlund, N.E., & Linn, R.L. (1990). *Measurement and evaluation in teaching*. Macmillan Publishing Company.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education,* 29(11), 1347-1362. https://doi.org/10.1080/09500690601007549

Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. The National Academies Press. https://doi.org/10.17226/18612

Hubberman, A., & Miles, M. (2005). *Analisis data kualitatif edisi terjemahan*. Universitas Indonesia.

Jones, M.G., Childers, G., Corin, E., Chesnutt, K., & Andre, T. (2018). Free choice science learning and STEM career choice. *International Journal of Science Education, Part B,* 1-11. https://doi.org/10.1080/21548455.2018.1534024

Kelcey, B., & Phelps, G. (2013). Considerations for designing group randomized trials of professional development with teacher knowledge outcomes. *Educational Evaluation and Policy Analysis,* 35(3), 370-390. https://doi.org/10.3102/0162373713482766

Kennedy, M.R. (2014). Engaging students in STEM education. *Science Education International,* 25(3), 246-258.

Miller, K., Sonnert, G., & Sadler, P. (2018). The influence of students' participation in STEM competitions on their interest in STEM careers. *International Journal of Science Education, Part B,* 8(2), 95-114. https://doi.org/10.1080/21548455.2017.1397298

Nadelson, L.S., McGuire, S.P., Davis, K.A., Farid, A., Hardy, K.K., Hsu, Y.C. et al. (2017). Am I a STEM professional? Documenting STEM student professional identity development. *Studies in Higher Education,* 42(4), 701-720. https://doi.org/10.1080/03075079.2015.1070819

Nugroho, O.F., Permanasari, A., & Firman, H. (2019). The movement of STEM education in Indonesia: Science teachers' perspectives. *Jurnal Pendidikan IPA Indonesia,* 8(3), 417-425. https://doi.org/10.15294/jpii.v8i3.19252

Reid, J., & Wilkes, J. (2016). Developing and applying quantitative skills maps for STEM curricula, with a focus on different modes of learning. *International Journal of Mathematical Education in Science and Technology,* 47(6), 837-852. https://doi.org/10.1080/0020739x.2016.1144814

Rismark, M., & Sølvberg, A.M. (2011). Knowledge sharing in schools: A key to developing professional learning communities. *World Journal of Education,* 1(2), 150-160. https://doi.org/10.5430/wje.v1n2p150

Roberts, T., Jackson, C., Mohr-Schroeder, M.J., Bush, S.B., Maiorca, C., Cavalcanti, M. et al. (2018). Students' perceptions of STEM learning after participating in a summer informal learning experience. *International Journal of STEM Education,* 5, 35. https://doi.org/10.1186/s40594-018-0133-4

Scaramozzino, J.M. (2010). Integrating STEM information competencies into an undergraduate curriculum. *Journal of Library Administration,* 50(4), 315-333. https://doi.org/10.1080/01930821003666981

Shahali E.H.M., & Halim, L. (2015). Bitara-STEM training of trainers' programme: Impact on trainers' knowledge, beliefs, attitudes and efficacy towards integrated stem teaching. *Journal of Baltic Science Education,* 14(1), 85-95. https://doi.org/10.33225/jbse/15.14.85

Shahali, E.H.M., Halim, L., Rasul, M.S., Osman, K., & Mohamad-Arsad, N. (2019). Students' interest towards STEM: A longitudinal study. *Research in Science & Technological Education,* 37(1), 71-89. https://doi.org/10.1080/02635143.2018.1489789

Sheffield, R., Koul, R., Blackley, S., Fitriani, E., Rahmawati, Y., & Resek, D. (2018). Transnational examination of STEM education. *International Journal of Innovation in Science and Mathematics Education,* 26(8), 67-80.

Shernoff, D.J., Sinha, S., Bressler, D.M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education,* 4(13), 4-13. https://doi.org/10.1186/s40594-017-0068-1

Siregar, Y.E.Y., Rahmawati, Y., & Suyono (2023). The impact of an integrated STEAM project delivered via mobile technology on the reasoning ability of elementary school students. *Journal of Technology and Science Education,* 13(1), 410-428. https://doi.org/10.3926/jotse.1446

Stohlmann, M.T., Moore, T.J., & Roehrig, G.H. (2012). Considerations for teaching integrated STEM Education. *Journal of Pre-College Engineering Education Research (J-PEER),* 2(1), 28-34. https://doi.org/10.5703/1288284314653

Tan, M. (2018). Why STEM? Why now? Educating for technologies, or technologies for education? *Learning: Research and Practice,* 4(2), 203-209. https://doi.org/10.1080/23735082.2018.1511275

Tuong, H.A., Nam, P.S., Hau, N.H., Tien, V.T.B., Lavicza, Z., & Hougton, T. (2023). Utilising STEM-based practices to enhance mathematics teaching in Vietnam: Developing students' real-world problem solving and 21st century skills. *Journal of Technology and Science Education,* 13(1), 73-91. https://doi.org/10.3926/jotse.1790

Vossen, T.E., Henze, I., De Vries, M.J., & Van Driel, J.H. (2019). Finding the connection between research and design: The knowledge development of STEM teachers in a professional learning community. *International Journal of Technology and Design Education*, 30, 295-320. https://doi.org/10.1007/s10798-019-09507-7

Wendt, J.L., Rockinson-Szapkiw, A., & Cordes, M. (2018). Examining the influence of a STEM certification model on female, minority science outcomes. *The Journal of Educational Research,* 111(6), 666-677. https://doi.org/10.1080/00220671.2017.1396437

Wiyarsi, A., Pratomo, H., & Priyambodo, E. (2020). Vocational high school students' chemical literacy on context-based learning: a case of petroleum topic. *Journal of Turkish Science Education,* 17(1), 147-161. https://doi.org/10.36681/tused.2020.18

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