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Assessing STEM Competences and Needs Alignment in Pre-service Chemistry Teachers

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Abstract

This study assessed the competence level in the STEM approach among university chemistry pre-service teachers. It employs a mixed-methods approach, integrating both quantitative and qualitative data collection. The questionnaire was administered to 218 pre-service teachers, a focus group discussion was conducted with 140 pre-service teachers in a group of 10 and interviews were conducted with 10 STEM field experts. The quantitative findings demonstrate the limited level of competence in the STEM approach among 2018 pre-service teachers. Statistically, there is no significant correlation between STEM competence levels and variables such as gender, specialization, or educational level because of generally low STEM literacy among pre-service teachers. The actual levels of STEM competencies of pre-service teachers in term of knowledge, skills and attitude do not align with their needs and expectations. The pre-service teachers' needs and expectations are higher than their competencies, suggesting the importance of designing STEM framework to enhance STEM competence and achieve the expected needs. The qualitative findings revealed similar findings of lower level of STEM Competences in term of STEM literacy, STEM-Pedagogical Content knowledge and STEM-Value. The study recommend designing and developing value-Based STEM Chemistry Framework and innovation focused STEM Module to cultivate innovation skills. The designing of STEM Professional Development Framework (STEM-PDF) is also recommended for innovative teaching methods to cultivate STEM-PCK, for enabling pre-service teachers to develop practical skills impacting STEM Competencies to their students.

Key Words: STEM Competence, STEM professional development, STEM-PCK, STEM Education

INTRODUCTION

The rise of Industry 4.0 presents a unique set of challenges for the future economy. Science Technology Engineering and Mathematics (STEM) approach cultivate skills which drive future economic growth through fostering innovation, meeting high-tech workforce demands, solving real-world challenges, and ensuring competitiveness in increasingly digital and automated world. In this regard, there is critical need for the younger generation to develop a strong foundation in STEM fields [1]. As demanded in the vision 2050 of the Revolutionary Government of Zanzibar, STEM proficiency is rapidly becoming an essential requirement for building the human capital that can drive innovation and growth in the future global economy [2]. According to several researches, STEM education has a vital role including technical skills development [3]. This perspective of STEM is linked to real-life activities for application and active learning modes that focus on learning beyond theories and procedures to include measurement and systems that enable students to experience learning in practice [1].

STEM is an integrated approach that is designed to teach the core concepts of science, technology, engineering, and mathematics, the curriculum program of STEM that were selected to equip the next generation with the necessary skills required by the labor force especially to embrace 21st century[4]. STEM education aims to produce students with excellent and balanced STEM Literacy [4]. Graduates of tertiary levels need to possess the ability to integrate STEM knowledge, skills, and values to recognize and address complex problems [1], [6]. STEM should also be viewed from a positive point that facilitates community life and the mastery of STEM basic knowledge and skills become essential tools in nurturing the values useful for universal well-being [1].

Despite the several studies conducted about STEM education, limited studies were done on an assessment of pre-service teachers' competence level regarding STEM approach particularly in Zanzibar. We believe that understanding the STEM competence level for pre-service teachers may be the starting point in addressing different challenges and developing appropriate innovative skills. Thus, the study assessed the competence level in the STEM approach among university chemistry pre-service teachers in Zanzibar.

Situation Analysis of STEM in Tanzania

The Connected for Science, Technology, Engineering, and Mathematics (STEM) project, as outlined by Open University Tanzania (OUT) in 2022, aims to pilot innovation and enhance secondary school teachers' capacities in delivering higher-order thinking STEM instruction. Tanzania takes part in these initiatives that focus on higher institutions to adapt and pilot the connected learning initiative together with other countries like Nigeria and Bhutan [7]. The study emphasizes the impact which analyzes innovation on teachers' knowledge, attitude, and practice of higher-order teaching and learning of STEM subjects, and concentrates on the innovation diffusion study which generates knowledge on processes of adoption of innovation for specific local contexts and the conditions that support scaling[7].By aligning with Tanzania's Education and Training Policy 2014 and contributing to SDG 4, the STEM project is poised to significantly improve the quality of STEM education in Tanzania by 2030.

Among the challenges addressed in the implementation of STEM projects in Tanzania include Teachers' workload, lack of access to ICT devices, and School breaks [7]. From the perspective of STEM students at the ordinary secondary level of education study biology and mathematics as compulsory subjects, while physics and chemistry are optional in Form Three and Form Four [8]. The STEM subject at the Advanced level is learned in combination with science subjects that can

also include technology and geography [8]. The 2020 situation analysis report from Open University revealed that many students are struggling with STEM subjects, with performance levels ranging from poor to very poor. Teachers are not using technology in their teaching despite the learning of teaching is by technology; [7]. This alarming trend of poor STEM performance, coupled with the underutilization of technology, highlights the urgent need for educational reform in Tanzania.
Several factors hinder effective STEM education in Tanzanian secondary schools. Some of the factors listed include a lack of library facilities, inadequate STEM teachers, and lack of hostels, household chores, limited moral value, and material support of families, students 'relatives, teachers, and economic prospects [9]. However, it is reported poor teaching methodology in science education, negative student attitudes, and lack of resources; equipped laboratories affect teaching and learning stem subjects in Tanzania [10]. There are few STEM-related training teacher professional development focusing on pedagogical content knowledge on science like those organized by the ministry of education in Tanzania, makes few teachers attend those programs to improve their skills [7]. The combination of these factors, as identified, creates a complex and multifaceted problem that requires a comprehensive solution to improve the quality of STEM education in Tanzania.

Theoretical and empirical Perspective on STEM assessment

The Constructivist and Problem-Based Learning

Jean Piaget who introduced the theory of constructivism argues that knowledge is not just transmitted from teachers to students but is actively constructed in the mind of learners, that learners create knowledge based on their prior knowledge, this demands the usage of learner-centric approach [11];[12]. In this regard, constructivist teacher viewpoints can be represented in Fig. 1 below.

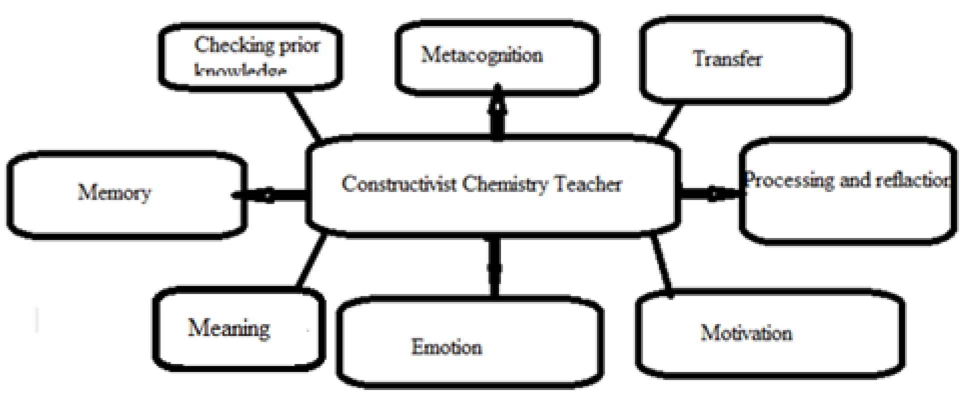


Figure 1: chemistry teacher's views consistance with Constructivist view points

The figure 1 model the constructivist chemistry teacher that captures a teaching approach that goes beyond delivering lecture, it focusing on about how students truly learn and engage with chemistry knowledge and skills.. At its Centre the model recognize that students don’t just absorb knowledge passively, they build it through linking with what they already understanding (prior knowledge), reflecting on their thinking (metacognition),and applying concepts to real situations(transfer). The model continue to show memory sticks when learning is meaningful, and deeper understanding comes from wrestling with ideas(processing) and stepping back to make sense of them(reflection). In this model teacher view human side of learning to maximize learning. Emotion is considered as fuel of engagement and not as a destruction while motivation thrives when students see how chemistry matters, whether in their daily life or solving bigger societal problems. This model of constructivist chemistry teachers ties well in value-based STEM education where the goal of chemistry education isn't just memorizing chemistry concepts, theories and principles but developing thinkers who can apply innovative skills ethically and creatively to solve societal problems.

Implications of Constructivism in teaching and learning chemistry

In these student-centered constructivism viewpoints direct student-teachers pedagogical skills to formulate specific learning strategies which are learner centric to enhance acquisition of chemistry practical skills. The figure 2 below summarizes specific learning strategies in teaching chemistry in classroom and laboratory practices.

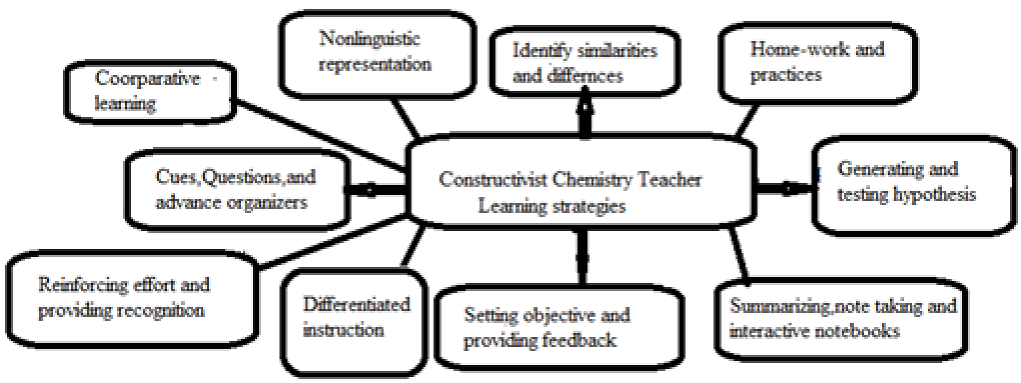
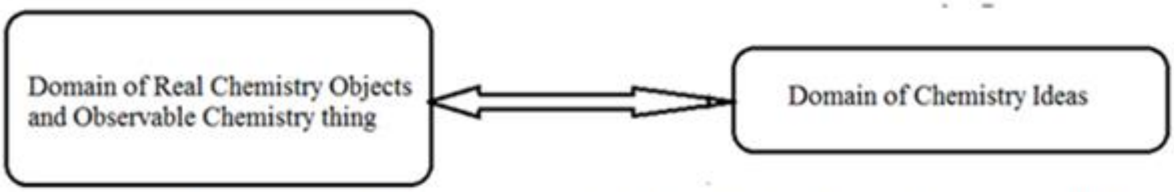


Figure 2: chemistry teacher's learning strategies consistance with Constructivist view points to enhance acquisition of practical skills

The figure 2 connect constructivist chemistry teaching strategies which are strongly support a value-based STEM Chemistry curriculum which combine academic and ethical growth. The strategies like cooperative learning and differentiated instruction promote collaboration, respect, and inclusion. On the other hand cues, questions, and feedback enhance responsibility, curiosity, and continuous improvement. The activities such as summarizing, hypothesis testing, and non-linguistic representation build critical thinking, creativity, and reflective learning. On other hand homework, effort recognition, and setting clear objectives foster discipline, independence, and perseverance. The strategies nurture students with STEM Chemistry innovation skills, ethics and social responsibility.
Problem-based learning is one type of constructivist learning theory that can be implemented in classroom practices [13]. The method gives opportunity to the students to experience learning through multiple given problems to solve. In this way, students can construct their own understanding of the subject through the problems they solve effectively [13]. The typical environment for problem-solving learning methods includes beginning with the problem for students to solve and learn about it, to mirror the complexity of real life students are given an ambiguous problem to solve, the inquiry model is used in classroom practices, students are required to present the conclusion of the problem-solving process but does not necessary require them to create a product as the result of their activity [13]. The process is driven by a defined problem to be solved.

Implications of Constructionist in teaching and learning chemistry

The practical work in chemistry can be explained in domain of real chemistry objects together with observable chemistry properties and events on one hand, and the domain of chemistry ideas on the other hand.



Practical work : linking two domain of Chemistry knowledge (Modified from Millar,2004)

The figure 3 explains the idea of transforming ideas into real objects useful in the society. This in line with the constructionist theory of learning by doing and making. Students design models of molecules, testing hypotheses in the laboratory, or prototyping solutions to societal problems. The learning is not just activities but ways to turn abstract concepts into something tangible. When students build something they become problem-solver, collaborators and are able to see theory in action. This in line with value-based STEM Chemistry which integrate idea into prototype for commercialization to solve societal problems. This enhances student active participation not only in the classroom but also in the real world.

Based on the idea of constructivism, Seymour Papert introduced his theory of constructionism, suggesting that new knowledge is created when students are actively engaged in developing some type of external artifact that they can reflect on and share with others [11]. Constructionist learning environments include the teacher acting as facilitator, learner's investigating, creating, and solving problems, learners collaborating, and students engaged in authentic tasks and given opportunities for feedback, and several opportunities for revision.

Project-based learning is a teaching strategy, one type of constructionist theory that involves the process of designing and developing an artifact as part of the learning process to solve problems [14]. The typical environment of for project-based learning method includes beginning with the product end in mind, production of an artifact that raises a problem to solve, students required to present the product they have created, it is driven by the end product, application of content knowledge and skills acquired in the production process are the real success for this method [14].

STEM Competence Levels and STEM Teaching Professional Development

The level of competence can be measured through understanding knowledge, application of skills in real life, and implementing values and ethics in everyday life. STEM education is how the knowledge learned in discipline helps to provide creative and innovative solutions to the existing problems to help students meet the needs of the job market, that teaching and learning involve students and equip them with critical thinking, problem-solving, creative and collaborative skills and ultimately help to establish the connection between schools, workplace, community, and global economy [1]. STEM processing and technical skills involve the capability and competence to explore, solve issues, design and produce products, and STEM values with ethics involve a positive attitude and morals and inculcate in teaching and learning is important to produce graduates who have knowledge and skills with great personality of being objective, systematic, consistent, think rationally, resilience, committed, open to change, courageous and open-minded [5].

STEM education as a learning approach to integrate STEM content, STEM Skills, and STEM values for solving contextual problems has been agreed by several studies in the literature [15] .According to NRC and NAE, the five main goals to be achieved in STEM education during the implementation are STEM Literacy, 21st-centurycompetencies, STEM workforce readiness, interest, and awareness as well as being able to make connections among STEM disciplines]. However, some studies show that educators including teachers are not familiar with STEM education [17]. In their study, they argue that there has been no reliable evidence on teachers' STEM pedagogical content knowledge of which educators in STEM education aims to increase to change teaching practices. This indicates the existence of knowledge among educators regarding the effective implementation of STEM practice [17]. Addressing this gap through professional development focused on STEM-PCK is crucial to translating theory into successful classroom practices.

The goals of schools and vocational schools have become factors causing the preparation of teachers like chemistry to use the STEM approach in their teaching. According to Tan, the STEM approach has drawn attention to educational reform, and become the foundation for future success as a significant component of educational reform efforts [18].It is revealed that STEM teaching and learning engage students and equip students with processing skills that are used to apply knowledge and skills to solve problems by processing science, and mathematics as well as design and computational skills in solving problems [1]. STEM teaching and learning process build mechanical skills which involve psychomotor to manipulative skills, handling materials, tools, and machines properly and safely. However, there is a gap between the desired situation and the current situation in the implementation of integrated STEM education and proposed professional development, training for teachers, collaborations between STEM subject teachers, and STEM expertise and community practices as the means to facilitate the implementation of STEM education [17].

This study focused on exploring the level of competence of the STEM approach based on the needs and expectations of pre-service teachers of Abdul-Rahman Al-Sumait University. Consequently, this study sought to answer the following questions:

1. What is the current level of STEM Competence among second-year chemistry pre-service teachers?
2. How do the actual levels of STEM competencies of pre-service teachers align with their needs and expectations?
3. What framework can be improved to enhance STEM competencies for chemistry pre-service teachers?

Methodology

Research design

The study employed a mixed methods approach that integrated qualitative and quantitative elements. This approach was utilized to gain a comprehensive and nuanced understanding of the level of STEM competencies among pre-service teachers. The rational of using a mixed method approach is in its strength to triangulate data sources, validate findings, and provide opportunity of depth and breadth in exploring the level of competencies. This design followed a convergent parallel strategy, where by quantitative and qualitative data were collected concurrently, analyzed independently, and then merged during the interpretation phase.

Participants

The study involved a total of 228 participants. These including 218 pre-service chemistry teachers and 10 subject matter experts. The pre-service teachers were selected from Abdulrahman Al-Sumait University where by 98 were in their first year and 120 were in their second year of Bachelor of Science with education program specialized in chemistry and other subject like biology, physics, geography and mathematics. These participants were purposively selected to represent varying chemistry combination and comparative analysis of competence levels across academic years.

The inclusion criteria for pre-service teachers included current enrollment in Bachelor of science with education specialized in chemistry, completion of at least one semester of academic coursework and readiness to participate in research.
Additionally, 10 chemistry education experts were purposively selected to contribute to the validation of research tools and provide expert assessments of competence indicators. These experts included university lecturers and experienced chemistry educators with minimum of a master's degree and at least five years of teaching experience.

Instrument and validation
The data were collected using quantitative surveys, qualitative interviews, and focus group discussions. In a quantitative survey, a structured questionnaire was administered to 218 pre-service teachers to self-assess their level of competence regarding STEM knowledge, skills and attitude, and STEM pedagogical skills in chemistry programs. The developed instrument comprises multiple-choice questions, Likert-scale items, and open-ended questions. Part 1 consist of demographic question, part 2 STEM Literacy where knowledge and skills were assessed. Part 3 consist of questions that assess attitude toward STEM. The survey was distributed to all enrolled undergraduate students in the first and second years of Abdulrahman Al-Sumait University. The focus group discussions were also conducted to discuss the level of STEM Literacy using140 pre-service teachers who formed groups of 10 students. In-depth interviews were conducted with a subset of pre-service teachers and ten experts to explore individual perspectives in greater detail. The objective was to obtain in-depth qualitative insights regarding the pre-service teachers' STEM-PCK. Interviews were designed and executed. Interviews were conducted in person each lasting 40 to 60 minutes. Interviews were recorded and transcribed for analysis. The instrument questionnaire, interview questions, and focus group discussion were adapted from the literature and validated by experts.

Data analysis
Descriptive statistics to identify dominant themes and trends in students' responses were used to analyze quantitative data. Inferential statistics using independent t-tests were employed to identify significant differences in the level of STEM competences, needs and expectations across three different demographic groups of gender, specialization, and educational level. This was chosen because it is suitable to compare two independent groups. Qualitative data from interviews were transcribed and analyzed thematically to uncover deeper insights into students' competence, needs, and expectations within STEM Chemistry programs. Open-ended responses were coded and analyzed thematically to identify common themes and insights. Focus group discussion were also recorded and analyzed. Transcripts were analyzed using thematic analysis to identify key themes and patterns. Coding was done manually and verified by second to ensure reliability.
Ethical considerations
Informed consent was obtained prior to data collection. All participants were informed about the purpose of the study, their rights, and the voluntary nature of their participation. Participants' responses were anonymized to ensure confidentiality. Data were stored securely and accessed only by the researcher. The study was approved by the management of Abdulrahman Al-Sumait University.

Findings

1. **What is the current level of STEM Competence among second-year chemistry pre-service teachers?**

Table 1: Competence Mean Scores by Gender

	Student Gender	N	Mean	Std. Deviation
Level of Competence	M	74	1.1351	.09426
	F	144	1.1119	.00763

The average mean score of the male student-teacher (1.1351) is slightly higher than that of female pre-service teachers (1.1119). The difference is 0.0232,which is very small while the standard deviation for males is higher (0.09426) than for females (0.00763),indicating that male competence scores are more spread out, while female scores are more consistent. This suggesting that male and female pre-service teachers' competence level is almost the same level with a slight increase of males compared to females.

Table 2 :Independent Sample Test

	F	Sig.	t	df	Sig.(2-tailed)
Level of Competence	1.788	.183	1.758	216	.080

An independent-sample t-test was conducted to compare the students' level of competence scores for males and females. There was no significant difference in scores for males (*M*=1.14, *SD*=.094) and females [*M*=1.11, *SD*=.092; *t*(216)= 1.758, *p*=. 080. The magnitude of the differences in the means is small (eta squared =.001). This was done to examine differences in competence scores between female pre-service teachers and male pre-service teachers. The results show that there is no significant difference, where the average competence scores of male pre-service teachers were 1.14(SD=0.094) and for female pre-service teachers were 1.11(SD=0.092), the results of t-vale of 1.758 and that of the p-value of 0.08. This p-value shows that there is no statistically significant difference in the conventional alpha level of 0.05. Moreover, the effect size was measured using eta squared (0.001),showing that small magnitude of difference between the groups. In general, the results suggest that while there is a slight variation in competence level score but not enough to be considered a meaningful difference. These results suggest that there was no statistically significant influence of gender on the level of competence scores in this sample.

Table 3: The Mean Score Level of Competence of Individuals Based on their Academic Year

	Academic Year	N	Mean	Std. Deviation
Level of Competence	1	98	1.1122	.08517
	2	120	1.1259	.9868

Analysis of competence level between academic year 2 and year 1 shows that year 2 (M=1.1259, SD=0.9868) scored higher on average compared to the students of Year 1(M=1.1122,SD=0.08517), However, there is a high standard deviation for second-year student which show significant variability in student performance. In contrast, the standard deviation observed for first-year students shows that the scores are near to the mean which indicates the uniform level of competence among the students.

Table 4:Independent Sample Test

	F	Sig.	t	df	Sig.(2-tailed)
Level of Competence	5.357	.022	-1.098	215.321	.273

An independent-sample t-test was conducted to compare the students' level of competence scores for the students 'academic year. There was no significant difference in scores for students' first year (*M*=1.11, *SD*=.085) and students' second year [*M*=1.13, *SD*=.099; *t*(215.32)= -1.098, *p*=. 273. The magnitude of the differences in the means was small (eta squared =.006). The results show that the observed difference is not statistically significant at a conventional level of 0.05. Additionally, the effect size measured using eta square(0.006) indicates a small magnitude of difference between the first year and second year. This revealed that there is no meaningful change in stem level of competence from the first year to the second year. In spite of the slight increase in students' STEM competence levels observed across academic years, the score variation was insufficient to establish a definitive relationship between academic progression and STEM Skill development.
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Table 5: The mean score Level of competence of individuals based on Specializations

	Specialization	N	Mean	Std. Deviation
Level of Competence	Biology-Chemistry(BC)	159	1.1167	0.08997
	Physics-Chemistry (PC)	26	1.1197	0.10852

The data in this table 5 compare the level of competence using score based on students' specialization. The biology-chemistry students have large sample size(N=159) score slightly higher mean(1.117) compare with students of specialization of physics and chemistry with the small sample size(26) which score lower(1.119). However, it is observed that within BC specialization students has shown higher variation in their competence level which is indicated by higher standard deviation of 0.08997. In contrast students in PC specialization show much lower deviation of 0.10852. The results suggesting that BC Students have higher score on average mean their competence level show higher variation between the students, whereas students in PC Specialization show more consistency around the lower score mean.

Table 6:Independent Sample Test

	F	Sig.	t	df	Sig.(2tailed)
Level of Competence	1.168	.0281	-1.151	183	.880

An independent-samples t-test was conducted to compare the students' level of competence scores for students' specialization. There was no significant difference in scores for biology- chemistry (*M*=1.12, *SD*=.090) and physics- chemistry [*M*=1.12, *SD*=.12; *t*(183)= -1.151, *p*=. 880. The magnitude of the differences in the means was small (eta squared =.000). The group show similar score of 1.12, with the standard deviation of 0.090 for biology-chemistry students and 0.12 for physics-chemistry students which show variability in their scores. The t-test value of -1.151 and the p-value of 0.0880 confirm no statistically difference while the effect size measured by eta square (0.000), indicate negligible variation in competence level between biology-chemistry and physics-chemistry. These results suggest that the specialization of biology-chemistry or physics-chemistry has no significant impact of pre-service teachers stem competence levels.

Table 7: The mean score Level of competence of individuals based on Specializations

	Specialization	N	Mean	Std.Deviation
Level of Competence	Biology-Chemistry (BC)	159	1.1167	.08997
	Chemistry-Mathematics (CM)	6	1.0926	.12989

Table 8:Independent Sample Test

	F	Sig.	t	df	Sig.(2tailed)
Level of Competence	1.041	.309	.634	163	.527

An independent-samples t-test was conducted to compare the students' level of competence scores for specialization. There was no significant difference in scores for Biology- chemistry (*M*=1.12, *SD*=.09) and chemistry- mathematics [*M*=1.09, *SD*=.13; *t*(163)= .634, *p*=. 527.The magnitude of the differences in the means was small (eta squared =.002). The t-test value of 0.634 and the p-value of 0.527 confirm no statistically difference while the effect size measured by eta square(0.002),indicate negligible variation in competence level between biology-chemistry and Chemistry-Mathematics. This result suggests that the specialization of biology-chemistry or physics-chemistry has significant impact of pre-service teachers stem competence levels.

Table 9:Group Statistics

	Specialization	N	Mean	Std. Deviation	Std. Error Mean
Level of Competence	BC	159	1.1167	0.08997	0.00714
	CG	27	1.144	0.08615	0.01658

Table 10:Independent Sample Test

	F	Sig.	t	df	Sig.(2-tailed)
Level of Competence	0.022	.883	1.468	184	0.144

An independent-samples t-test was conducted to compare the students' level of competence scores for specialization. There was no significant difference in scores for Biology- chemistry (*M*=1.12, *SD*=.09) and chemistry- geography [*M*=1.14, *SD*=.086; *t*(184)= .1.468, *p*=. 144.The magnitude of the differences in the means was small (eta squared =.012).

Results of Focus Group Discussion

Table 11: Data Analysis of Focus Group Discussion

Categories	Excerpt based on Current Status	Level of Competences
STEM Theory and knowledge	"We don't Know	Low level of STEM Literacy
Hands-on-activities	"We can conduct activities	Low Level of STEM-PCK
Project-Based Learning	"We can't supervise projects"	
Discovery Learning	"We are not familiar with it"	
Inquiring base learning	"We can use it in teaching"	
Cooperative Learning	" We can use discussion method no other"	
Practical Work	"We can do experiment but need more help"	
Laboratory Skills	"We can conduct experiments but need help"	
Systematic Project Execution	"We cannot manage Projects"	Low STEM Value Attitude
Value-driven Prototype	"We cannot make with Prototypes"	

Table 11 show that pre-service teachers were unaware about STEM approach from the meaning, how it work and why is needed. Most of them were STEM illiterate. These results comply with the self -

assessment survey conducted to assess the level of STEM competence for pre-service teachers participated in this research. The results find the level of competence based on Level of STEM Literacy is low. These results contribute to the literature which similarly reported that educators including teachers are not familiar with STEM education [17]. The results also show that pre-service teachers can practice activities that can be used in STEM teaching and learning process like hands-on-activities however unaware of integrating the concept of STEM using those teaching method which make the results to suggest moderate level of competence based on the level of STEM-PCK. Similarly, it is reported poor teaching methodology in science education lack of facilities affect teaching and learning stem subjects in Tanzania [10]. The results show that students are unable to manage and handle projects and also are not confident in designing prototype which make the level of competence using level of STEM Value to be low. This results agreed with the study of Shimbi, reported that poor negative students' attitude which affect their STEM teaching and learning process[10]. Comparing quantitative data analysis and qualitative data analysis it revealed that the level of STEM competence is regarded to be low that can be said is in the stage of developing.

2. **How the actual level of STEM competences of pre-service teachers align with their needs and expectations?**

Table 12

		Average Needs	**Level of Competence**
Average Needs	Pearson Correlation	1	.013
	Sig(2-tailed)	-	.85
	N	218	218
Level of Competence	Pearson Correlation	.013	1
	Sig(2-tailed)	.85	-
	N	218	218

The relationship between students' needs and students' level of competence was analyzed using Pearson's correlation. There was a very weak positive correlation between the two variables [r=.013, n=218, p=.85], which was not statistically significant. These results suggest that there is no meaningful relationship between the pre-service teachers' perceived needs and their actual level of STEM competences. The alignment of what they feel they need and what they actually know or can do in STEM is very weak and not statistically significant.

Table 13

	Mean	**Std. Deviation**	**N**
Average Needs	4.4842	0.47165	218
Level of Competence	1.1198	0.09289	218

The results in the table provide summary of statistics for two variables, average needs and level of competence for sample size of 218. The average score of Average needs is 4.4842 with the standard deviation of 0.4716, this show that while average needs score is relatively high, there is variation across the sample. In contrast, the average level of competence is 1.1198, which is smaller standard deviation of 0.09289. This indicates that pre-service teachers' level of competence is consistent with less variability. In general, average need score show moderate variation and level of competence score is tightly clustered around the mean value.

Table 14: Relationship between Expectations and Level of Competences

		Average Needs	**Level of Competence**
Average Expectations	Pearson Correlation	1	.127
	Sig(2-tailed)	-	.062
	N	218	218
Level of Competence	Pearson Correlation	.127	1
	Sig(2-tailed)	.062	-
	N	218	218

The relationship between students' expectations and students' level of competence was investigated using Pearson product-moment correlation coefficient. There was small non-significant positive correlation between the two variables [r=.127, n=218, p =.062]. This results suggest that there is no meaningful relationship between students expectation and the level of competence of students.

Competence levels did not vary significantly by gender, academic year or academic specialization among pre-service teachers at Abdulrahman Al-Sumait University.

3. **What improvement framework can be made to enhance STEM Competencies for chemistry pre-service teachers?**

Table 15: Thematic analysis on improving the level of STEM competences

Categories	**Themes**
STEM Theory and knowledge	STEM Literacy
Hands-on-activities Project-Based Learning Discovery Learning Inquiring base learning Cooperative Learning Practical Work Laboratory Skills	STEM-PCK
Systematic Project Execution Value-driven Prototype	STEM Value

STEM Literacy

Ability to demonstrate understanding of proper knowledge of STEM concepts and theories in application of STEM skills is crucial for building STEM competence of a chemistry student- teacher. However, pre-service teachers participated in this study have limited level of competence of STEM Literacy.

Excerpt: "Actually I don't know even the meaning of STEM"

Analysis shows that most teachers are not familiar with the concept of STEM which made them unable to guide students to develop skills in STEM approach. The analysis revealed that foundation knowledge of STEM and STEM theory, knowledge and practical skills application will effectively improve the level of STEM competence. The study argues that there is research basis for construct of STEM Literacy as an intersection and integration of the skills and practices required in all STEM disciplines likewise other research differentiate the specific skills and practices that are found in all of the STEM disciplines thus distinguish S.T.E.M. literacies to represent all the relevant literacies (scientific, technological, engineering, mathematical literacy) [19]. Some studies indicate that STEM literacy development is difficult and can take at least decade to develop STEM education in a country [20].

STEM-PCK

Pedagogical content knowledge (PCK) is the basic, context-specific knowledge that teacher activate when reflecting on practice and executing instruction that cultivate the greatest experiences for students learning [21]. The ability to design teaching methodologies which cultivate STEM processing and STEM mechanical skills is the real STEM-PCK.

Excerpt: "Teachers should have ability to use several teaching methods like project-based learning approach to design teaching and learning activities that students can learn practical work"

STEM-PCK include organizing practical work, laboratory skills, organizing cooperative learning strategies, using inquiry base learning, project-based learning approach are essential for building innovation skills to the students. Shulman combine pedagogy and content to propose pedagogical content knowledge [22], and suggest that PCK is the most significant component of successful teaching practices[23].According to Twaddle and Smith, successfully teach STEM, educators need pedagogical content knowledge which enable student to benefit from the communication, collaboration, critical thinking, and problem solving skills gained from STEM education[24]. The figure 4 below show pedagogical skills for acquisition of chemistry practical skills for innovation

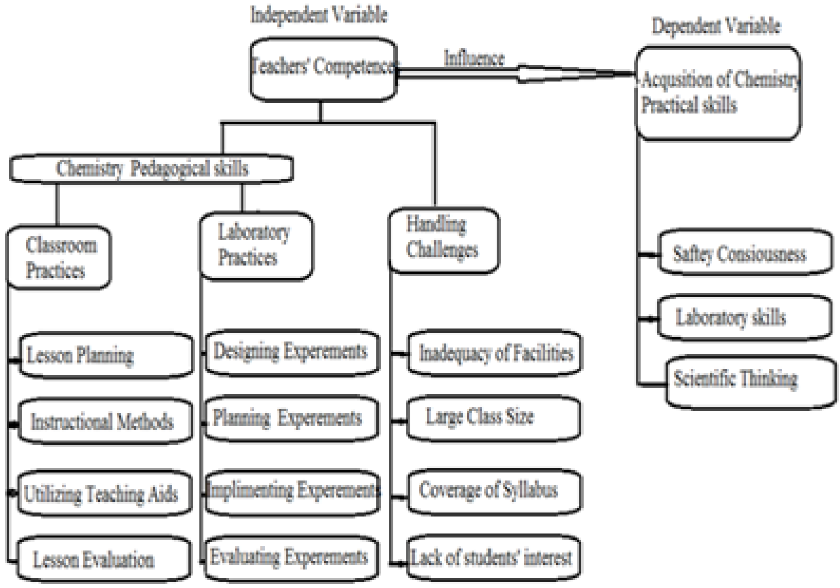

Figure 4: Pedagogical Skills for Aquisition of Chemistry Practical Skills

STEM-VALUE

This is based on cultivation of students' positive attitude and moral which will guide to handle life ethically. The positive attitude include moral of doing work and self-sustain.

Excerpt: "Teachers have to be model of good moral and conduct as well as should be able to design products using their skills to motivate students to learn"

Analysis: Role model is important to the students that in STEM teachers have to show example by making some innovation of prototype which show the capacity of using innovation skills for production. The results suggest that to improve the level of competence STEM Literacy by through STEM theory and knowledge is to build STEM-Pedagogical Content knowledge such as project-based learning, discovery method, practical work and cooperative learning strategies and cultivate STEM Value which give courage to handle projects and design prototype for commercialization. STEM application can be resolved on a moral basis and suggesting to the teachers on how to maintain STEM practices within an ethical framework [25]. The figure 4 above describe conceptual framework for pre-service teacher's competences to influence acquisition of chemistry practical skills that foster STEM innovation.

Conclusion and Recommendations

The study reveals that current level of STEM Competence among first and second year chemistry pre-service teachers exhibit limited but satisfactory. Despite variations in gender, educational level, and specialization, no significant differences were observed. This suggesting systematic STEM illiteracy across all groups. Design and Implementing a STEM Professional development framework (STEM-PDF) to train pre-service teachers in innovative pedagogies including inquiry-based learning and project-based learning.. Integrate ethics-driven STEM practices to foster moral responsibilities alongside technical skills.

The actual levels of STEM competences of pre-service teachers do not align with their needs and expectations. The pre-service teachers' needs and expectations are higher than their competences suggesting importance of designing and developing STEM educational program to enhance STEM competence to achieve the needs as expected. The study recommend designing and developing value-

Based STEM Framework and innovation focused value-based STEM Chemistry Module prioritizing hands-on experiments to cultivate innovation skills for real-world problem-solving.
The systematic STEM illiteracy and misaligned expectations can be solved by designing frameworks that combine ethics, innovation and pedagogy which can be achieved by advocating for institutional adoption of the STEM-PDF, designing Value-based STEM Framework, developing Value-based STEM Module and policy support.

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