



## Pre-Service Teachers' Conception of an Effective Science Teacher: The Case of Initial Teacher Training

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### ABSTRACT

The purpose of this study was to find out pre-service teachers' conceptual understanding of an effective science teacher. A total of 100 pre-service teachers from two unique colleges of education in a municipal assembly in Ghana were selected to participate in this case study. In each college, the pre-service teachers were selected through a stratified random sampling procedure. The pre-service teachers responded to a test, and their responses were open-coded and constantly compared to come out with six themes. The findings show that an effective science teacher creates a conducive environment for students to learn science. It is, therefore, recommended that college science educators should prepare pre-service teachers to develop appropriate knowledge, strategies, and techniques needed to create an environment conducive for learning science.

**Keywords:** College of education, concept, effective, pre-service teachers, science teacher

### INTRODUCTION

The role of teachers in teaching scientific concepts is crucial. Teachers' role in science lessons can be defined as teacher-, book-, or student-centered (Johnson, Zhang, & Kahle, 2012; Tuomi & Tweed, 2006). California Commission on Teacher Credentialing (CCTC, 2003) reported that "effective science teachers are critical part of an education system that serves all the people of the State of California" (p. 10). However, the concept of effective teaching is broad and general in the science education literature (Hipkins et al., 2002). The areas of



effective teaching identified by Hipkins and his colleagues are (a) teachers' high expectations of students, (b) a wide range of instructional strategies, (c) sound knowledge of the content, (d) deep understanding of aims and objectives of the science curriculum, (e) recognition of students' outcome, and (f) the capacity to provide students' feedback. In addition, the attributes of an effective science teaching are the ability to teach through authentic and investigative experiences, a meta-cognition of professional expertise, and teaching confidence and competence that meet professional standards and public expectations (Blake & McNally, n.d.).

Effective teaching is not a matter of science teachers knowing the content and having the necessary skills and sufficient experiences of teaching (Clough, Berg, & Olson, 2009). The content of science deals with selecting appropriate subject material for each level and involving students in making meaning of the targeted materials (Tuomi & Tweed, 2006). An effective science teaching is independent of teachers' content knowledge but depends upon teachers' pedagogy. That is, the teachers' ability to teach science content is the most important factor to consider under effective science teaching (CCTC, 2003). Teachers are required to have skills and knowledge in the scientific concepts, which is described as strong scientific content knowledge. This is because teachers with strong content knowledge are more likely to assist students in making meaning of scientific concepts (Banilower, Cohen, Pasley, & Weiss, 2008).

The CCTC (2003) required science teachers to demonstrate competencies in the scientific concepts to be effective. Science teachers must demonstrate their acquisition of many complex skills. The acquired complex skills must be demonstrated through communication and demonstration of concepts, principles, processes, attitudes, and application of scientific and technological knowledge equally to male and female students from diverse ethnic and cultural backgrounds.

With respect to acquired complex skills, Blake and McNally (n.d.) reported that effective science teachers integrate innovative teaching and learning practices into their classroom interactions. According to CCTC (2003),

Science teachers should also be creative, innovative, flexible, and enthusiastic about their own appreciation of science. They need to be knowledgeable about laboratory and field practices, safety concerns, and the history and philosophy of science. Science teachers should be informed about the application of science, and about careers based on science (p. 11).

The integration of information and communication technology in science lessons can help in the effective teaching of scientific concepts (Aina, 2013; Guzey & Roehrig, 2009; Osman, Halim, & Meerah, 2006; Slavin, Lake, Hanley, & Thurston, 2012).

Çimer (2007) considered lesson plans as an element that can contribute to effective science teaching and noted that effectively planned lessons involves active student participation in lessons. An effective science teaching includes (a) lesson design that deals with planning, instructional strategies, (b) assigning roles and resources, (c) implementation techniques that deal with pacing, (d) classroom management, (e) teacher questioning and confidence, and (f) classroom culture (Tuomi & Tweed, 2006). Teaching at a higher-order level, such as analysis, synthesis, and evaluation requires that lesson plan and its implementation to provide students with opportunities to make mistakes. In such a case, feedback plays a significant role (Sealfon, 2012).

For effective teaching, students' previous knowledge relevant to the new knowledge should be mastered, by eliciting, providing opportunities to confront, and reflecting on the previous knowledge (Banilower et al., 2008). Six principles of effective science teaching are teaching that (1) takes care of students' existing ideas and conceptions, (2) provides students with opportunities to apply new scientific concepts or skills in different contexts, (3) provides students with opportunities to actively participate in science lessons, (4) provides students with opportunities to learn through inquiry-based learning, (5) encourages cooperative learning among students, and (6) provides students with continuous assessment and feedback (Çimer, 2007).

Blake and McNally (n.d.) described effective science teaching as appreciating the effects of students' voices in science lessons. The work of Johnson et al. (2012) found that effective science teachers spent some fraction of the minutes of the science lessons to engage students in a whole-class discourse, sharing ideas, and challenging ideas. Those science teachers have room for students' questions on scientific concepts being studied in class. Science teachers should encourage students' interactions by appreciating students' ideas, writing ideas on the board, incorporating students' ideas into instruction, and asking students to explain further their ideas (Clough, Berg, & Olson, 2009). Clough and his colleagues added that this does not imply that all students' ideas about scientific concepts should be accepted right even when they are incorrect.

Prenzel and Duit (2000) analyzed a distinct feature of Japanese mathematics and science teachers teaching and reported that the teachers tolerated and explicitly supported alternative solutions given by students. Teachers who want to maintain interaction with students should carefully listen to and respond sensitively to what students say during lessons. Doing so creates a conducive learning environment for students to make public their thinking (Clough et al., 2009).

Science teachers with a reasonable command of the English language can teach students effectively (CCTC, 2003; Osman et al., 2006). Thus, the idea of effective teaching is related to (a) science language and literacy development, (b) engaging students in science talk where they describe, hypothesize, explain, justify, argue, and summarizes, (c) engaging students in group work such as project, and (d) providing students with opportunities to learn to use the scientific method to hypothesize, collect and analyze data, and draw a conclusion. Science teaching should, therefore, integrate the teaching of scientific inquiry, science discourse, and language and literacy development in a curriculum that is open to the socio-cultural linguistic environment (Stoddart, Bravo, Solis, Mosqueda, & Rodriguez, 2011).

Effective science teachers do not make decisions about students' learning in a vacuum but consider factors such as desired student goals, how students learn, and interactions among instructional practices. They decide what to teach by reflecting and considering how students learn. That is, understanding students help teachers make effective decisions about the content to teach, activities to use, materials to use, instructional strategies to use, and teacher behavior to exhibit (Clough et al., 2009).

Wieman (2008) asserted that effective science teaching engages students in deep thinking about scientific concepts at an appropriate level. It further monitors and guides students' thinking to be more of an expert-like and considers meaningful experiences where students are intellectually engaged in scientific concepts. Effective science teaching can occur when learning experiences are linked with the objectives of teaching scientific concepts.

Teachers provide opportunities for students to make meaning of ideas and concepts through concrete learning goals and relating the ideas and concepts to everyday experiences (Banilower et al., 2008). Students' motivation helps to make the meaning of concepts and ideas. However, effective teaching should balance the effects of intrinsic and extrinsic motivators to influence meaning-making (Banilower et al., 2008).

One other way science teachers engage students is through the use of questions. These questions bring forth students' learning. Hence, the nature of questions and the process of asking questions contribute to effective science teaching (Çimer, 2007). Effective science teaching should provide students with opportunities using skillful questioning, class discussion, and explanations of sense-making after they engage in scientific activities (Banilower et al., 2008).

Though there are a number of research studies in the area of effective science teaching, the literature on the meaning teachers who doubled as students make of effective science teaching is limited. The purpose of the study was to find out pre-service teachers' conceptual understanding of an effective science teacher. The research question that guided the study was: "*How do pre-service teachers, from initial teacher training, consider as an effective science teacher?*"

The current study has become necessary to provide science education literature with the concept of an effective science teacher, from the perspective of pre-service teachers, and implications for practice. This study would help science education researchers and educators to appreciate students' expectations of teachers teaching science and science-related subjects and courses. The findings from the study can inform best practices in teaching science.

## **RESEARCH SITE, PARTICIPANTS, AND METHODS OF THE STUDY**

This study was a case study employing qualitative methods to find out pre-service teachers' conceptual understanding of an effective science teacher. The study was conducted with pre-service teachers in one of the municipal assemblies in the Ashanti Region of Ghana. In the municipal assembly, the pre-service teachers were selected from two colleges of education.

The new education reforms upgraded from teacher training colleges to colleges of education in 2004 to award diploma in Ghana. The colleges of education were affiliated to teacher education-oriented universities and their entry requirements were raised to the level of the universities. The reforms, further, established teaching and licensing coordinating body to ensure professionalism in the education sector. The reforms became necessary as the government of the Republic of Ghana intended to have an efficient teacher education system that can supply professionally qualified teachers for pre-school, primary, and secondary schools (Ministry of Education, Youth, and Sports [MOEYS], 2004).

In total, there were 46 government colleges of education throughout the country that turned out graduates to handle basic school subjects such as integrated science. Of the 46 colleges of education, nine were located in the Ashanti Region in Ghana. The only male college of education amongst the 46 was in the Ashanti Region. In the municipality where the male college was located, there was another college for females. I took an interest in conducting the current study in this municipality because of the unique characteristics of the two colleges.

The pre-service teachers from the two colleges pursued general teacher education programs after they could handle most of the basic school subjects. Hence, the pre-service teachers were offered integrated science as one of the courses in the three-year teacher education programs. Second-year pre-service teachers were involved in the study. The second-year pre-service teachers were selected as they studied three integrated science courses at the time of the study. These courses were Integrated Science I, Integrated Science II, and Methods of Teaching Integrated Science. The outlines of the topics in each course were as following.

1. Integrated Science I: Teaching the cell, respiratory system in humans, structure and functions of flowering plants, ecosystem, elements, compounds and mixtures, measurements, energy, work and power, light energy, solar system, hazards, vegetable crop production, farming systems, and nature of the soil.
2. Integrated Science II: Teaching reproduction and growth in humans, heredity, movement of particles in and out of cells, circulatory system in humans, food and nutrition, infections and diseases, rate of reactions, metals and non-metals, water, force and momentum, motion and pressure, machines, climate, pets and parasites.
3. Methods of Teaching Integrated Science: Teaching the nature of science, instructional methods, profile dimension, instructional planning, curriculum materials, improvisation of teaching and learning materials, science practical skills, and safety in science (Institute of Education, 2014).

The demographics of pre-service teachers who participated in the study are presented in Table 1.

**Table 1.** Demographics of participants involved in the study

College	Year group	Sex	N	n	%
A	second	Male	222	50	22.5
B	second	Female	198	50	25.3
Total			420	100	23.8*

N = The number of targeted participants, n = The number of selected participants, \* = The average percent of the participants

As seen in Table 1, there were 222 second-year pre-service teachers in the male college and 198 second-year pre-service teachers in the female college, who were targeted to participate in the study. The number of pre-service teachers from each college was stratified into five groups as regular classroom arrangement in the colleges. From the five groups, 10 pre-service teachers were randomly selected, giving a total of 50 from each college. Hence, the research instrument was responded by a total of 100 pre-service teachers. The participant size of 23.8% was relatively small but became necessary as the study adopted qualitative methods and partly because the randomization permitted for generalization of the findings to the entire participants.

A five-item test, constructed by the author of the study, was used as the main mode of data collection. In the test, there was a statement as “*explain to your Circuit Supervisor; who you consider as ‘an effective science teacher,’*” which served as the basis of analysis in this study. The pre-service teachers were not limited on what to write on the concept freely. The

purpose of using this type of instrument was to examine the pre-service teachers' teaching and learning of integrated science experiences in primary and high schools. Currently, at the college of education, where the pre-service teachers can take the Methods of Teaching Integrated Science course, they could freely describe an effective science teacher from their experience (Cepni, Ulger, & Ormanci, 2017) and expectation.

The validity of the test was dependent upon how the Colleges of Education Integrated Science End of Semester test items were crafted. The items were crafted in such a way that they were in high order thinking. Before the actual study, there was a pilot study of the test instrument with 20 second year pre-service teachers from another college in another region of Ghana. The analysis from the pilot study revealed some common themes and showed that the test was reliable. Reliability was further ensured by avoiding to make the test look like 'normal' assessment situation.

The actual study was conducted in the same week with the pilot study. The author of this study traveled from the female college to the male college to administer the test in person. This prevented the pre-service teachers from sharing ideas. They responded to the test in a time span between 30 and 60 minutes. In this study, sufficient data on pre-service teachers' conception of an effective science teacher would be provided for the determination of transferability.

The explanations given by the pre-service teachers were open coded and constantly compared. Themes were then generated based on the meaning the author of this study made of their explanations of an effective science teacher. The themes were:

1. Selection and usage of instructional strategy,
2. Selection and usage of teaching and learning materials,
3. Consciousness of professional demands,
4. Creation of conducive environment,
5. Interest in students' academic improvement, and
6. Knowledge of content and instructional strategy.

To ensure credibility of the themes, 20 pre-service teachers, 10 each, selected through simple random from the two colleges, were asked to cross-check themes used to analyze their explanations. The themes were, finally, peer-reviewed by three researchers in science education.

## **EFFECTIVE SCIENCE TEACHER**

The research question sought to find out how pre-service teachers considered as an effective science teacher. The presentation and discussion of the results were done using the six themes while taking care of the divide between male and female pre-service teachers. In most instances, sub-themes were used. A minimum of two sample statements and codes such as (M001) and (F100) for male and female pre-service teachers respectively were used to support each sub-theme. The proportions of explanations of the pre-service teachers in relation to each theme and the subthemes are presented in Table 2.

**Table 2.** Proportions of themes on effective science teacher

Theme	%	Subtheme	%
Selection and usage of instructional strategy	74.0	Activity-based instruction	22.0
		Practical-based instruction	15.0
		Text-based instruction	17.0
		Application-based instruction	11.0
		Integrated-based instruction	9.0
Selection and usage of teaching and learning materials	33.0	-	33.0
Consciousness of professional demands	65.0	Duty consciousness	21.0
		Time consciousness	44.0
Creation of a conducive environment	89.0	Interesting-learning env't*	12.0
		Welcoming-learning env't	13.0
		Encouraging-learning env't	15.0
		Experience-learning env't	10.0
		Structured-presentation env't	9.0
		Assessment-based learning	11.0
		Language-friendly env't	10.0
		Student-question answering	9.0
		Interest in students' academic improvement	20.0
		Students' academic improvement	5.0
		Students' performance in examination	6.0
Knowledge of content and instructional strategy	48.0	Teacher knowledge of content	37.0
		Teacher knowledge of content and pedagogy	11.0
Indistinctive explanations	7.0		7.0

env't\* = environment.

The percentages were calculated based on the number of the 100 pre-service teachers explaining the concept of an effective science teacher under each theme. As seen in Table 2, it was clear that the pre-service teachers associated most of their conceptual understanding of an effective science teacher with the learning environment (89.0%) and less with the academic improvement of students (20.0%).

### *Selection and Usage of Instructional Strategy*

This theme describes the ability of science teachers to select and use appropriate instructional strategies to meet the learning needs of students. As seen in Table 2, 74.0% of the pre-service teachers explained that an effective science teacher teaches scientific concepts and ideas using appropriate instructional strategies that help students to develop conceptual understanding. For example, a pre-service teacher stated that *“the right methods of teaching adopted by the teacher in the lesson delivery make him/her an effective science teacher”* (M028), and another pre-service teacher indicated that *“teachers are considered as effective science teachers due to the mode and style of teaching ie, they use appropriate teaching methods”* (F067). The sub-themes are presented as follows.

**Activity-based instruction:** Some of the pre-service teachers explained that an effective science teacher teaches scientific concepts through activity-based instruction. For example, a pre-service teacher mentioned that *“an effective science teacher uses methods of teaching which are activity-oriented”* (M005), and another pre-service teacher stated *“an effective science teacher is the one who uses the methodology in teaching that engages students in activities”* (M034).

In other instances, the pre-service teachers explained that an effective science teacher teaches scientific concepts using instructional strategies where students are actively involved in the lesson. For example, a participant noted that *“is someone who engages students actively in the science lesson. This is because the more students practice the more they understand”* (M044), and another participant commented that *“he/she adopts a lesson that actively involves learners to participate effectively in the teaching and learning process”* (F079).

**Practical-based instruction:** This subtheme describes an instruction where science teachers teach through practical works. Some of the pre-service teachers explained that an effective science teacher teaches scientific concepts and ideas through practical lessons. For example, a pre-service teacher mentioned that *“an effective science teacher is a person who makes the lesson practical and always involves the students”* (M037), and another pre-service teacher stated that *“he/she make teaching take practical form”* (F093).

In another instance, the pre-service teachers explained that an effective science teacher instructs science through practical works that are laboratory-based to enhance student understanding. For example, a pre-service teacher indicated that *“effective science teachers take students to the science lab to study scientific chemicals and some happenings of substances”* (F067), and another one documented that *“he usually leads us to do our practical aspect of learning in the laboratory which makes us to easily understand the science lesson”* (F083).

Some of the pre-service teachers explained that an effective science teacher instructs science through practical lessons as opposed to theoretical approaches. The practical lessons enhance the first-hand experience. For example, one participant mentioned that *“... he makes teaching and learning of science more practical but not theoretical, ie it is real”* (M001), and another participants noted that *“an effective science teacher makes teaching of science take a practical form and you feel it so that the topic will not just theory theory and theory”* (F084).

**Textbook-based instruction:** In this case, instruction is not rooted in just transferring concepts and ideas from textbooks. Some of the pre-service teachers explained that effective science teacher does not teach science like transferring information from textbooks where they do not have control over the content. For example, a pre-service teacher stated, *“an effective*



teacher does not base his/her teaching solely on textbooks but think and come out with interesting related ideas” (M029), and another pre-service teacher indicated “... he does not read frequently from lesson notes and textbooks when teaching but try as much as possible to demonstrate that he understands what he is teaching” (M040).

In another instance, the pre-service teachers explained that an effective science teacher teaches scientific concepts and ideas using practical approaches but not through the transmission of ideas and concepts from science textbooks. For example, two statements of pre-service teachers were “he is a teacher who makes the lesson practical and always involves students but not reading from textbooks” (M032), and “an effective science teacher should not be bookish but practical enough” (M035).

Some of the pre-service teachers explained that an effective science teacher does not teach scientific concepts and ideas by using lectures. In lectures, since there is only reciting, teachers and students are hardly involved in the teaching and learning process. For example, one participant said, “effective science teacher should not lecture by talking alone but teach to the understanding of his/her learners by involving them” (F079). Another participant stated, “... an ineffective science teacher uses the lecture method in teaching and his students are not involved” (F080).

Application-based instruction: In this instance, the pre-service teachers explained that an effective science teacher instructs scientific concepts and ideas using an approach where students can apply the concepts to everyday life experiences. For example, a pre-service teacher noted that “a teacher I consider as effective is the one whose teaching has great impact on the students, ie the students understand, interpret, and apply what they have learned in real life situations” (M013), and another pre-service teacher indicated that “is the one who can relate the science to a real life situation” (F051).

In other instances, the pre-service teachers explained that an effective science teacher instructs science using real-life illustrations. This makes learning easy for students. For example, two statements of pre-service teachers were “an effective science teacher is the teacher who uses real life illustrations to explain various scientific concepts. This makes learning of science very easy” (M039), and “an ineffective science teacher does not give real examples or illustration and only does the talking without involving students’ ideas or views (F091).

Integrated-based instruction: This subtheme involves using more than one strategy in instruction. Some of the pre-service teachers explained that an effective science teacher teaches scientific concepts and ideas using integrated approaches and techniques. An effective science teacher varies instructional strategies and techniques when necessary to suit the learning needs of students. For example, a pre-service teacher mentioned, “when students fail to adopt to a method of teaching, an effective science teacher quickly changes the method to suit the needs of the students” (M033), and another pre-service teacher stated “the science teacher is considered as an effective because he/she uses most of the methods in a science lesson. He varies methods based on the topic he is teaching” (M050).

Others went further to explain with examples of strategies and techniques that an effective science teacher integrates to teach science to help students develop conceptual understanding. For example, a participant noted, “an effective science teacher is someone who uses some methods such as activity method, demonstration method, and project method in teaching but not lecture method” (M031), and another participant indicated that “an effective

*science teacher uses methods like activity method, demonstration method, and problem solving method to make the learners acquire skills and knowledge about concepts well” (M036).*

#### *Selection and Usage of Teaching and Learning Materials*

Teacher selection and usage of teaching and learning materials (TLMs) describes a teacher's knowledge and ability to use TLMs to bring effective teaching and learning. This effective teaching and learning can lead to students' conceptual development in scientific concepts and ideas. Of the 100 pre-service teachers, 33.0% of them conceptualized the idea of an effective science teacher in terms of TLMs. Some of the pre-service teachers explained that an effective science teacher provides TLMs in lessons for interactions of students. For example, one pre-service teacher said, *“an effective science teacher is the one who teaches using teaching and learning materials” (M023)*, and another pre-service teacher stated, *“effective science teachers make students interact with the TLMs in their lessons” (F090).*

In other instances, the pre-service teachers explained that an effective science teacher uses appropriate TLMs in teaching scientific concepts and ideas. For example, two statements of pre-service teachers were *“... he uses appropriate teaching and learning materials in his lessons” (M045)*, and *“... also, if the person does not use the appropriate science tools for teaching, he/she is not an effective science teacher” (F097).*

Others explained that an effective science teacher knows using TLMs in teaching science. For example, a participant statement was *“an effective science teacher must have the ability to select and use suitable TLMs for the lesson delivery” (M016)*, and another participant statement was *“... he is also someone who is knowledgeable in the use of TLMs in his lesson delivery” (F072).*

Some pre-service teachers explained that an effective science teacher selects and uses TLMs in teaching to enhance students' conceptual understanding of scientific concepts and ideas. For example, one pre-service teacher explained that *“... he is a teacher who uses TLMs to make learners get real understanding of content and apply them to real life situations” (M009)*. Another pre-service teacher said, *“an effective science teacher uses all the tools in the lab to explain to the understanding of students” (F071).*

In other instances, the pre-service teachers explained that an effective science teacher instructs science by using TLMs to attract students' interest in learning scientific concepts and ideas. For example, there were some explanations as *“an effective science teacher is the one who make good use of all the teaching and learning materials to arouse desire of learners to learn” (M001)*, and *“an effective teacher is a teacher who is teaching with teaching and learning materials to make things clear and attractive to students” (M047).*

Some of the pre-service science teachers explained that an effective science teacher uses locally available materials in the absence of conventional TLMs to bring effective science teaching and learning. An effective science teacher can improvise conventional TLMs. For example, one pre-service teacher stated that *“he/she should use improvised materials to involve students practically in science lessons which will help them grasp the concept and ideas in science” (M015)*, and another one indicated that *“an effective science teacher is someone who teaches using teaching and learning materials and is capable of improvising in the absence of the actual TLMs” (M022).*

### *Consciousness of Professional Demands*

Of the 100 pre-service teachers, 65.0% considered an effective science teacher who is aware of expectations about him or her and mentally ready. Since students come to school to learn, every minute of their encounter with science teachers is important, and the pre-service teachers believe that science teacher consciousness of professional demands make teachers effective. Teacher consciousness of professional demands contains subthemes as duty and time consciousness.

**Duty Consciousness:** Teacher duty consciousness describes a science teacher's preparedness, the ability to gather all materials needed to teach scientific concepts and ideas to students. Effective teachers come to class well prepared and use instructional time well.

Some of the pre-service teachers explained that an effective science teacher prepares in advance prior to the science lesson. Some related excerpts were "... also, he/she must have enough time to prepare before a lesson" (M018), and "an effective science teacher prepares in advance before coming to class" (F076).

In another instance, the pre-service teachers explained that an effective science teacher prepares in advance, helping him/her to build up confidence. This results in students overcoming their difficulty in learning scientific concepts and ideas. For example, a pre-service teacher stated that "an effective teacher is confident because he prepares well in advance to produce higher students' achievements" (M012), and another pre-service teacher noted that "an effective science teacher is a teacher who prepares before the lesson, teaches with confidence helping his/her learners to perform" (M029).

Some of the pre-service teachers explained that an effective science teacher is creative who can find possible immediate environmental materials to relate scientific concepts and ideas to enhance students' conceptual understanding. For example, a participant mentioned that "an effective science teacher is someone who try as much as possible to find something in the community, within his busy schedule, to relate every topic for easy student understanding" (M022), and another participant indicated that "is someone who is creative in teaching science and uses time very well" (F058).

In another instance, pre-service teachers explained that an effective science teacher is resourceful. Some excerpts about this subtheme were "an effective science teacher is someone who is resourceful in the field of science" (M005), "an effective science teacher is simply resourceful" (F074), and "... also, an effective science teacher is resourceful" (F076).

Others explained that an effective science teacher is hardworking who can use materials available to improve the quality of teaching scientific concepts. This reflects on students' achievements. For example, one pre-service teacher stated that "an effective science teacher works hard to improve the quality of teaching helping students to do well" (M021), and another pre-service teacher mentioned that "an effective science teacher is hardworking whose effort enables his/her students to excel in examinations and assessment" (M028).

**Time consciousness:** This subtheme describes science teachers' awareness and use of instructional time to the benefit of students. Science teachers, being aware of the importance of instructional time for student learning, are expected to use time effectively. Some of the pre-service teachers explained that an effective science teacher is a teacher who is regular or always in class for science lessons. Such an effective science teacher is not necessarily punctual but always available to students. Some related excerpts with this subtheme were "an effective science teacher is the one who never misses his instructional hours and is always

there" (M041), "he is the person who is always available when his time of teaching is due" (F078), and "I consider someone as an ineffective science teacher if the person does not attend classes regularly and when we need him, he is nowhere to be seen" (F100).

In another instance, the pre-service teachers explained that an effective science teacher is regular and timely in science lessons. This simply implies that an effective science teacher is punctual in attending to science lessons. For example, a pre-service teacher noted that "an effective science teacher is a science teacher who is very punctual in class" (F056), and another pre-service teacher stated that "a science teacher is considered ineffective if he/she is not punctual in class" (F089).

Others explained that an effective science teacher is punctual, makes up for any lost instructional time that may have happened due to some circumstances beyond his or her control. Some excerpts about this subtheme were "he also does not miss his period of teaching and even when he misses the class he schedules the lesson to another time. ie, if there is extra-curricular activity, he re-schedules another lesson" (F065), and "an effective science teacher ensures punctuality always, if and when he/she missed, will try and schedule time for the topic to be treated" (F066).

Some of the pre-service teachers explained that an effective science teacher plans and teaches within the given instructional time. An effective teacher makes effective use of instructional time. For example, a participant said that "a teacher I consider as effective uses measures for teaching carefully and also plan and teach within the time allotted to science subject" (M013), and another participant mentioned that "is a person or a science tutor who makes good use of his/her time in class during lesson and not use other teacher's lesson period" (F081).

In another instance, the pre-service teachers explained that an effective science teacher takes time in teaching scientific concepts and ideas to the students. An effective teacher avoids rushing students through scientific concepts. For example, a pre-service teacher indicated that "he takes his time to teach without rushing through the presentation of the lesson" (F064), and another pre-service teacher noted that "when it comes to practicals, he finds enough time to demonstrate concepts to students" (F085).

Further on teacher taking time in teaching, the pre-service teachers explained that an effective science teacher takes time in teaching in order to explain scientific concepts for the understanding of students. Some related excerpts with this subtheme were "... also, an effective science teacher is a teacher who will have time to explain to students aspects of topics that is difficult to understand" (M027), and "he is effective because he always have time to explain again and again when students do not understand the topic" (F077).

Others explained that an effective science teacher is simply time conscious. Some excerpts about this subtheme were "he must be time conscious as a professional teacher" (M002), "an effective science teacher is a teacher who is time conscious" (F069), and "an effective science teacher is the one who is time conscious" (F082).

#### *Creation of a Conducive Environment*

Creation of a conducive environment theme describes a teacher's ability to organize teaching and learning environment that creates a friendly environment for students to learn. It is the area where an overwhelming proportion of the pre-service teachers (89.0%) used as the basis for the explanation of the concept of an effective science teacher. Some of them explained

that an effective science teacher creates a conducive environment for students' learning of scientific concepts and ideas. For example, a pre-service teacher stated that *"he creates a conducive learning environment for learning to take place"* (F076), and another one mentioned that *"is the one who provides a conducive environment for teaching and learning process"* (F082). The rest of the results under this section are presented in subthemes.

**Interesting-learning environment:** This subtheme describes a learning environment that is interesting and enjoyable. Some of the pre-service teachers explained that an effective science teacher creates an environment conducive by making the process of teaching and learning interesting and enjoyable to students. Some related excerpts with this subtheme were *"she is a teacher who makes the science lesson interesting and enjoyable. You can't afford to miss her lessons"* (M029), and *"... he also makes teaching of science interesting. Is a teacher I will want to be in his lesson always"* (F084).

Furthermore, some of the pre-service teachers explained that an effective science teacher creates an interesting learning environment for students by using teacher-made questions. These questions should be centered on nature within the immediate surroundings of students. In using questions, an effective teacher should have the capability to respond to student questions. Some excerpts about this subtheme were *"an effective science teacher is the one who starts a lesson with questions about nature. This is because sound teaching usually begins with questions that are interesting and familiar with students, not with phenomena outside their range of perception, understanding or knowledge, students need to be acquainted with what is around them"* (M044), and *"an ineffective teacher does not make science learning interesting because when you ask question in class he will say go and find it yourself"* (F077).

**Welcoming-learning environment:** This subtheme explains an environment where there are good human relationships between science teachers and students. In this case, students feel belonging. Regarding this subtheme, a pre-service teacher said, *"he is someone who is friendly and have passion for teaching"* (M008), and another one stated, *"he is a friendly teacher"* (M032).

Some of the pre-service teachers explained that an effective science teacher creates a welcomed-learning environment by having good personal relationships with students. For example, a participant mentioned that *"he/she is the one who is able to establish good personal relation between him/herself and the learners and even his/her co-teachers"* (F072), and another participant indicated that *"an effective science teacher is the one whose interpersonal relationship with students is basically professional. ie he doesn't abuse his students emotionally"* (F088).

Others explained that an effective science teacher creates a welcomed-learning environment. In this environment, students learn scientific concepts and ideas by showing love from the teacher. Some related excerpts with this subtheme were *"he is a teacher who loves and has empathy for students"* (M009); *"he is a teacher who love and cherish his/her students"* (M033), and *"he is caring, showing love and affection to the students he is teaching"* (M040).

In another instance, the pre-service teachers explained that an effective science teacher creates conducive learning by being open-minded to students' criticisms on happenings in science lessons. Some excerpts about this subtheme were *"an effective science teacher is an open-minded person and creating room for constructive criticism"* (M021), and *"an effective science teacher is also the one who is open-minded and have the humility character. Because of that students learn and excel in examinations"* (M028).

Encouraging-learning environment: This is where science teachers create a conducive environment by motivating students to learn scientific concepts and ideas. For example, a pre-service teacher stated that *“an effective teacher motivate students to learn science”* (M030), and another pre-service teacher indicated that *“an effective science teacher engages and motivates students to learn, and build on their existing knowledge and understanding”* (M043).

Some of the students explained further that an effective science teacher creates an encouraging environment for students to learn science by praising students. The students are praised for doing their best. An effective teacher can praise the academic sides of students. Some related excerpts with this subtheme were *“he is the teacher who praises students base on academics and nothing else to encourage them”* (M0011), and *“someone who encourages students to raise questions about the materials being studied, help them learn to raise questions clearly enough to begin to search for answers and also suggest to them some productive ways of finding answers”* (M044).

Others explained that an effective science teacher creates an encouraging environment that is motivating enough by building the confidence of students. This is achieved as the teacher demystifies science to make it less difficult for students. Some excerpts about this subtheme were *“an effective science teacher builds his/her students confidence in learning of the subject science”* (M045), and *“an effective science teacher is the teacher who is able to clear the notion that ‘science is a difficult subject’ from the minds of students and does everything possible to help students to build our confidence in science as a subject”* (M046).

Experience-learning environment: In a conducive environment, an effective science teacher provides students with experiences needed to learn science. Regarding this subtheme, a pre-service teacher mentioned that *“is someone who provides abundant experiences for students using tools and sound equipment such as calculators and microscope”* (M030), and another one stated that *“students learn best when they actively participate in the learning process using materials and effective teachers create such conditions for students”* (M044)

Some of the pre-service teachers explained that in an experienced-learning environment, teachers use effective measures to control the teaching and learning process to aid students' learning. For example, a participant indicated that *“he must be discipline enough to control students and serves as a mentor to the students”* (M004), and another participant stated that *“the teacher creates conducive atmosphere for learning by having control over the class”* (F067).

Structured-presentation environment: In this instance, science teachers use careful and orderly presentations of scientific concepts and ideas to create conducive learning environments for students. Some related excerpts with this subtheme were *“an effective science teacher makes sure he/she teaches systematically and orderly”* (M009), and *“he delivers his lesson systematically”* (F065).

Some of the pre-service teachers further explained that an effective science teacher creates conducive environments through systematic presentations, helping students to develop conceptual understanding. Some excerpts about this subtheme were *“his lesson is always structured in appropriate steps which he follows systematically to ensure majority of the students get maximum understanding of the lesson”* (M041), and *“an effective science teacher is a teacher who teaches systematically and make sure that his students understand the concept he is teaching”* (F057).

In other instances, the pre-service teachers explained that an effective science teacher creates conducive environments through sequential presentations via teaching from simple to complex. Regarding this subtheme, a pre-service teacher said, “*an effective science teacher is sequential in the presentation of topics in science, i.e. simple to complex*” (M021), and another one stated, “*an effective teacher arranges units or topics sequentially in a systematic order. That is teach from simple to complex*” (F097).

Others explained that, in structured-presentation environments, science teachers use reasonable space of time. That is, an effective science teacher does more to avoid rushing students in science lessons. For example, a pre-service teacher indicated that “*... also, he does not rush in teaching but takes time to teach step-by-step for everybody to understand*” (F063), and another a pre-service teacher mentioned that “*an effective science teacher makes sure that almost all the students understand the topic and also assist the weak ones and does not just rush through*” (F068).

Some of the pre-service teachers explained that an effective science teacher creates structured-presentation making sure that students understand one concept or topic before moving on to the next. For example, a participant noted that “*an effective science teacher makes sure that learners understand the content taught before he/she continues his/her teaching*” (M009). Another participant stated that “*a person can be considered as an effective science teacher if he makes sure that everyone understands the first topic before moving to the next topic*” (F094).

Assessment-based learning environment: This is where science teachers raise and use teacher-made questions, class exercises, and class tests/quizzes to create an enabling environment for students’ learning. Some related excerpts with this subtheme were “*is a teacher who uses assessment to keep his/her learners busy during learning*” (M049), and “*an effective science teacher gives a kind of exercise that will demand a lot of research for about a week*” (F075).

Some of the pre-service teachers explained that an effective science teacher creates a conducive learning environment with assessment by monitoring students’ works. Some excerpts about this subtheme were “*an effective science teacher monitors and evaluates learners in science class*” (M006), and “*an effective science teacher gives students enough worked examples for them to practice and goes round to make sure everyone does the example*” (F098).

Others explained that an effective science teacher creates a conducive learning environment for students by scoring their assessment tasks to identify weaknesses and strengthens. In this environment, an effective science teacher provides students with feedback. Regarding this subtheme, a pre-service teacher mentioned, “*an effective science teacher assess the students’ leaning early and often attends to the students’ difficulties or misconceptions*” (M030), and another pre-service teacher stated that “*... ie a science teacher who always give an assignment to his/her students, marks and discusses it for the students to know their mistakes and shortcoming in order for them to rectify their mistakes*” (M048).

In other instances, the pre-service teachers explained that an effective science teacher creates a conducive environment for students’ learning through the distribution of questions to all students in science lessons. Some related excerpts with this subtheme were “*ineffective science teacher gives opportunities to very few students to respond to questions in class and at times always use one or two students’ answers as example*” (F093), and “*an ineffective*

*science teacher always points some particular students to answer questions and eliminate others” (F100).*

Language-friendly environment: This is where science teachers create conducive environments by using suitable language. An effective science teacher uses simple vocabulary that can be understood by all students in a science lesson. Some excerpts about this subtheme were *“the ability to express him/herself to the learners’ understanding makes somebody an effective science teacher” (M028), and “is a person who uses simple vocabularies understandable to his students in teaching process” (F078).*

In other instances, an effective science teacher creates a conducive environment by communicating scientific concepts and ideas to students very well. Since scientific terminologies are not common in everyday life communication, they may seem new and strange to students. An effective science teacher can bring these terminologies to the level of students’ understanding. For example, a pre-service teacher indicated that *“he/she is a teacher who communicates science terminologies very well to my understanding” (M017), and another pre-service teacher noted that “a science teacher always explain any scientific key word very well which is introduced to the lesson. At times it makes you feel that science is not that difficult to learn” (F052).*

Student-question answering environment: This subtheme is related to an environment created as a result of teacher positive attitude towards questions asked by students. An effective science teacher can be tolerant of all students’ questions and issues in science lessons. For example, a participant said that *“he must appreciate and tolerate all that his students present and the questions we ask” (M0029), and another participant mentioned that “he accepts questions and answers from his students whether good or bad” (F096).*

Some of the pre-service teachers explained that an effective science teacher creates a conducive environment for students’ learning by responding to or addressing all students’ questions. Regarding this subtheme, a pre-service teacher mentioned that *“he finds time to address his students questions and problems they encounter during the lesson” (M031).* Another pre-service teacher stated that *“a science teacher who is ineffective when you ask question he will ask you to wait till he finishes teaching” (F084).*

With respect to teacher creation of a conducive environment, some of the pre-service teachers’ explanations of an effective science teacher could not be placed under any of the subthemes. Some related excerpts were *“an effective science teacher creates an environment that will help students develop knowledge and skills they need in the classroom” (M012), and “he reviews learners’ RPK and builds on them” (F071).*

### *Interest in Students’ Academic Improvement*

Teacher consideration of students’ characteristics describes effective teachers’ place on student characteristics and progression. An effective science teacher considers students as an important element in the teaching and learning process. Only 20.0% proportion of the pre-service teachers conceptualized effective science teachers in terms of student academic improvement.

Consciousness of students’ characteristics: This is where a science teacher is aware of students he or she is teaching. An effective science teacher considers the class average of students’ performance and does not teach above the class average. Some excerpts about this subtheme were *“... he/she assesses students in a class base on the average learner” (M002),*



and “*a science teacher is effective if he always considers the average of the students and does not teach above the class*” (M006).

In other instances, an effective science teacher considers individual intellectual abilities in teaching scientific concepts and ideas to a class of students. Some excerpts about this subtheme were “*an effective science teacher considers the intellectual abilities of all students*” (M011), and “*an effective teacher does not discourage students but considers the intellectual abilities of students different individuals*” (M022).

Others explained that an effective science teacher considers the academic level of students in teaching scientific concepts and ideas. This consideration influences the selection of instructional strategies and materials. Regarding this subtheme, a pre-service teacher mentioned that “*a teacher who understands his/her learners’ level of understanding in all situations and correct them if possible ... because the Level 100 students need different instructional strategies compared to Level 200*” (M039), and another pre-service teacher stated that “*he considers level and stages of the learners in order to know the techniques, strategies, and methods to use in teaching*” (F079).

Students’ academic improvement: This is a situation where a teacher shows a keen interest in students’ academic progression. An effective science teacher always provides students with an opportunity to work towards improving their shortfalls in learning science. Some related excerpts with this subtheme were “*a teacher who is always happy to be with and teaches his/her learners to improve on their learning*” (M049), “*is a teacher who has interest in what he/she is teaching and is happy teaching the subject to help our class improve on our weakness*” (F055), and “*he/she is always interested in his/her students’ academic improvement especially when weak students excel*” (F073).

Students’ performance in examinations: An effective science teacher is conscious of students’ passing or failing at the end of semester examinations. The pre-service teachers believe that an effective science teacher prepares students to perform creditable well in examinations. Some related excerpts with this subtheme were “*he is a teacher who is able to study past examination questions and is able to predict likely examination questions for students to pass*” (M029), “*at least 75% of the students of an effective science teacher pass term examinations*” (M021), and “*his students can recall concepts in exams time and pass examinations*” (F085).

### *Knowledge of Content and Instructional Strategy*

Of the 100 pre-service teachers, 48.0% related an effective teacher to teacher’s demonstration of control over the content and instructional strategies selected to teach the content. The pre-service teachers were interested in seeing science teachers blending the content with the pedagogy to suit student learning. The results are presented under sub-themes as teacher knowledge of content and teacher knowledge of content and pedagogy.

Teacher Knowledge of Content: This subtheme describes the demonstration of a science teacher’s conceptual understanding of scientific concepts, ideas, and principles when teaching. Some of the pre-service teachers explained that an effective science teacher demonstrates sufficient knowledge in science to students. Some excerpts about this subtheme were “*an effective science teacher should have the in-depth knowledge of the topic before teaching*” (F068), and “*an effective science teacher is knowledgeable enough in the science topics especially Chemistry and Physics aspects*” (F078).

In another instance, the pre-service teachers explained that an effective science teacher demonstrates a good understanding of scientific concepts and ideas in teaching. An effective science teacher can justify the content being taught. For example, a pre-service teacher indicated that *“an effective science teacher is a teacher who understands and knows what he/she is teaching and can justify it”* (M021), and another pre-service teacher noted that *“an effective science teacher is a teacher who understands and knows what he/she is teaching and can proof it beyond reasonable doubt”* (F060).

Others explained that an effective science teacher is abreast of the current state of scientific knowledge. An effective teacher has the knowledge and conceptual understanding of new happenings in the scientific domain. Some related excerpts were *“to be effective science teacher one must be abreast in the science topic. ie new things are happening and she should know them”* (F071), *“he/she is abreast with time”* (F072), and *“an ineffective science teacher is not abreast of time ie does not know new things in science”* (F076).

In other instances, the pre-service teachers explained that an effective science teacher conducts researches to update his/her knowledge and conceptual understanding of scientific concepts, ideas, and principles. For example, a related participant's excerpt was *“an effective science teacher is someone who does a lot of research works to update his/her knowledge what he is teaching”* (M022), and another participant's excerpt was *“is a teacher who does learn further and does a lot of research about the subject and what is new in the teaching of science”* (F056).

With respect to research, some of the pre-service teachers further explained that an effective science teacher does research, which enables him/her to handle scientific concepts and ideas very well. Some excerpts about this subtheme were *“an effective science teacher is the teacher who does research and does not deal without molded theories of science”* (M001), and *“an effective science teacher is someone who revise or read wide at home before he comes to deliver his lesson to the understanding of learners”* (M040).

Some of the pre-service teachers explained that an effective science teacher demonstrates his/her knowledge of the content by giving detailed explanations to scientific concepts, ideas, and principles when teaching. For example, a pre-service teacher stated that *“he/she must be a teacher who is able to explain details of concepts, laws, and terminologies of science to his/her students”* (M017), and another pre-service teacher noted that *“an effective science teacher is the one who explains concepts clearly to his/her learners”* (F079).

Teacher knowledge of content and pedagogy: This subtheme describes a science teacher's demonstration of conceptual understanding and the ability to use appropriate instructional strategies for teaching science. Although a limited number of responses fell into this subtheme, it is worth considering Shulman's (1987) evolutionary presentation in this area. Some related excerpts with this subtheme were *“an effective science teacher is the one who is updated to scientific findings and can impact that knowledge, skills, and attitudes to students through the use of suitable methods of teaching”* (M007), and *“teacher who understands and knows what he/she is teaching and can justify it using the appropriate approach”* (F056).

Some of the pre-service teachers explained that an effective science uses appropriate instructional strategies to present the content. Those instructional strategies eliminate boredom and sustain students' interest in science lessons. For example, a participant indicated, *“he uses appropriate teaching methods in teaching science to sustain our interest in learning science. ie he knows the subject matter and the right methods of teaching”* (M0027), and another

participant said, “an effective science teacher uses approaches to avoid boredom during the science class. He/she combines the subject matter with the pedagogy very well” (M042).

### *Indistinctive Explanations*

Indistinctive explanations describe the pre-service teachers’ explanation of the concept of an effective science teacher that cannot be grouped under any of the six themes. This accounted for only 7.0% of the pre-service teachers’ conceptual understanding of an effective science teacher. Some of these ungrouped excerpts were “he is the teacher who is able to train students to be problem solvers” (M001); “he is able to complete the syllabus” (M002), “he is the one who does not praise him/herself for what he knows or teaches” (M004), and “an ineffective science teacher is a teacher who always thought we know” (F077).

## **DISCUSSION**

The findings of this study show that the selection and usage of instructional strategies can be the basis of referring to a science teacher as effective or not (Hipkins et al., 2002). An effective science teacher should select and use instructional strategies such as activity-based, practical-based, and application-based instructions that place the student at the center of the teaching and learning process. The findings of this study suggest that an effective science teacher should not use only one strategy in teaching. Such science teachers use more than one strategy and vary the strategies when it becomes necessary. It is, therefore, recommended that science teachers should adapt to the use of integrated-based instruction by using more than one strategy in a science lesson, as indicated by Blake and McNally (n.d.), to cultivate the culture of varying instructional strategies for pre-service teachers.

The finding that an effective science teacher uses TLMs in the process of teaching and learning shows that modern-day science cannot do away with the selection and usage of TLMs. This indicates that it is not a matter of just using TLMs but to select and use appropriate TLMs that can assist students in making meaning and attracting them to learn science-related courses and subjects. It is, therefore, recommended that science teachers in different countries, where it is difficult to acquire and use conventional science equipment and facilities to teach science, should practice improvisation. Additionally, pre-service teachers from colleges of education should be prepared in a way that they could select and use appropriate conventional and improvised TLMs for effective teaching of science. Advance preparation is essential in science teaching, and effective science teachers are expected to consider the preparation as the best practice. It makes science teachers resourceful and confident, thereby delivering quality scientific knowledge to students.

The findings on creating conducive environments indicate that a high premium is placed on the environment in which students learn science (Clough et al., 2009). These conducive environments should be interesting, welcoming, and encouraging. It can be achieved through (a) systematic presentation, (b) the use of appropriate instructional strategies and TLMs, (c) respect for students’ views, and (d) the use of simple language that helps students to make meaning of science (Tuomi & Tweed, 2006). It is, therefore, recommended that teacher education institutions should prepare pre-service teachers to acquire the appropriate knowledge, strategies, and techniques needed to create an environment comfortable for students’ learning of science.

The findings show that an effective science teacher should place a premium on students' characteristics during the teaching and learning process. Teachers should, therefore, consider the class average, individual abilities, and students' level of knowledge in teaching science (Çimer, 2007). It is, therefore, recommended that science educators should prepare pre-service teachers to acquire the skill of identifying students' characteristics to inform the selection and usage of content, strategies, techniques, and TLMs in teaching science.

Another attribute that, an effective science teacher is measured with teacher instructional time consciousness. The findings show that an effective science teacher should be regular and timely making effective use of instructional time. This should be for the advantage of students' learning. Science teachers should be interested in the output of students and adopt a means of helping students to improve continuously. This is because an attribute of an effective science teacher is related to students' output (Hipkins et al., 2002; Tuomi & Tweed, 2006). Therefore, it should be noted that students' academic excellence could imply that teachers are teaching effectively.

With respect to teacher knowledge of the content, the findings reveal that an effective science teacher should have an in-depth understanding of scientific concepts, ideas, and principles, and be able to explain such science to the understanding of students as reported in other studies (Banilower et al., 2008; Hipkins et al., 2002). Science teachers could acquire such an in-depth understanding by reading wide (or researching) and not to be satisfied with the knowledge of science acquired sometime back. It is, therefore, recommended that science educators should organize their instruction in ways to prepare pre-service teachers to develop the attitude of searching for new knowledge at all times.

The combined effect of teacher knowledge of science and instructional strategy is seen as another attribute of effective science teaching (CCTC, 2003). This confirms Shulman's (1987) assertion that teacher knowledge of content helps in the development and usage of tools for effective teaching and learning process. It is, therefore, recommended that science educators should prepare pre-service teachers to transform scientific knowledge to the benefit of students they would be teaching.

## CONCLUSION

The study has helped in describing how students in general (and pre-service teachers in particular) conceptualize an effective science teacher. The concept of an effective science teacher is explained in six themes including (1) selection and usage of instructional strategy, (2) selection and usage of teaching and learning materials, (3) consciousness of professional demands, (4) creation of a conducive environment, (5) interest in students' academic improvement, and (6) knowledge of content and instructional strategy. The current study has added to the literature by providing six themes of conceptualizing an effective science teacher. Most pre-service teacher (like all other students) prefers to identify effective science teacher with the ability to create a conducive learning environment. Science teachers need to appreciate and understand these perspectives with which students consider their teaching practices.

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