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Training Needs of Science Teachers for Teaching Scientific and Engineering Practices through a Networked Professional Learning Community: A Mixed Methods Study

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Abstract

The current research aimed to identify training needs of science teachers for teaching scientific and engineering practices through a questionnaire that was applied to (17) science teachers to investigate their needs for networked professional learning community (NPLC). The research in data collection and interpretation was based on the techniques and conditions of mixed research design. The results of the current research showed that science teachers need continuous professional learning opportunities that are aligned with the changing needs of their students and with the Next Generation Science Standards (NGSS); as the results indicate a gap between the description of scientific and engineering practices and their application in the classroom for the science teacher. As teaching transfer to science standards, it is necessary to provide teachers with network professional development opportunities that meet their specific needs by engaging in "model lessons" in light of science standards, learning instructional strategies to support science standards, reading science standards, and design lesson; Teachers can gain the knowledge, skills, and confidence they need to effectively implement the new standards and support student learning. By collaboration in networked professional learning communities; science teachers can keep up with the latest research, instructional strategies, and technological advances that can alignment with scientific and engineering practices. Additionally, future research could examine how networked professional learning community (NPLC) can further enhance collaboration and resource sharing among science teachers.
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Keywords: *Three-Dimensional Learning (3-D), Scientific and Engineering Practices (SEP), Networked Professional Learning Community (NPLC), Training Needs, Mixed-Method Research Design, Qualitative Data Analysis (QDA).*

Introduction

Networked professional learning enables teachers to collaborate with their colleagues, both within and outside their schools. This collaboration fosters the exchange of ideas, resources, and strategies, and promotes networked professional learning. Through networked professional learning communities, teachers can connect with colleagues across the country or even globally, allowing diverse perspectives and a broad range of expertise to inform their practice. The science standards emphasize the importance of three-dimensional learning, which combines disciplinary core ideas, scientific and engineering practices, and crosscutting concepts. Collaboration with fellow teachers provides opportunities to co-develop lesson plans, assessments, and instructional strategies that align with the science

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standards framework. By harnessing the collective expertise of the network, teachers can enhance their understanding of the science standards and develop effective instructional practices (Skrimponis and Makris, 2020).

Conceptual Framework and Related Studies

Three-Dimensional Learning (3-D)

The science standards include three-integrated dimensions that are important when teaching and learning science due to the learning outcomes they achieve; hence, it is called Three-dimensional of learning science, which represents an integrative perspective between specialized disciplinary core ideas, crosscutting concepts, and scientific and engineering practices (NRC, 2014); therefore, the National Research Council (NRC, 2012) called for weaving the three- dimensions together in curricula, education, and assessment in what is called Performance Expectation, which requires learners to demonstrate mastery of content, practices, and concepts in an integrated manner; which supports their learning better (NRC, 2015), meaning that the standards emphasize what learners should be able to do, and it is difficult to expect learners to succeed in this unless teachers become able to teach for three-dimensional learning; therefore, effective professional development has a role in preparing teachers for this paradigm shift (Nollmeyer and Bangert, 2017).

Henry's study (2022) aimed to enhance the use of (3-D) learning approach in science classrooms in low-performing schools. This study used (3-D) professional learning to build teacher capability, as well as enhance collaboration and create engagement across the region among science leaders. Data collected and analyzed from classroom observations, student surveys, and teacher interviews revealed enhanced use of (3-D) learning and increased engagement across the region in implementing (3-D) educational practices.

Scientific and Engineering Practices (SEP)

Scientific and engineering practices express the expected performances of students in science standards, show the relationship between basic sciences and engineering and technological fields, and develop their ability to observe, collaborate, discuss, and dialogue. Scientific phenomena are a fertile field for designing lessons and units according to science standards, especially those related to current events, such as: floods, climate change, solar eclipses, lunar eclipses, earthquakes (Richman, Haines, and Fello, 2019, p. 203). The standards document included eight scientific and engineering practices, as explained by Mason (2019), which are:

1. **Asking questions (for science) and defining problems (for engineering):** In science, we are interested in asking questions with the aim of explaining a phenomenon or identifying a theory, and scientific questions are characterized by the fact that the answers are scientific explanations or evidence.
2. **Developing and using models:** Models are used in science to represent and simplify a system or phenomenon; to help answer questions, form explanations, and link ideas together.
3. **Planning and carrying out investigations:** Scientific investigations (inquiries) are conducted to describe a phenomenon, or test a theory or model by identifying and providing data; to be used in explaining the phenomenon.
4. **Analyzing and interpreting data:** Data is collected and analyzed, and presented in a form that clarifies and explains the relationship between them; so that the meaning of the data, its importance, and the possibility of using it as evidence can be highlighted.
5. **Using mathematics and computational thinking:** These are two important things for communicating and extracting data results, and this is done through various and simple arithmetic and statistical transactions.
6. **Constructing explanations (for science) and designing solutions (for engineering):** The goal of science is to reach and clarify explanations that cause a phenomenon to occur, and in engineering, problems are solved by designing solutions.
7. **Engaging in argument from evidence:** By integrating into evidence based on proof, and being able to identify weaknesses and strengths; in order to reach the best ways to explain natural phenomena, and evaluate the opinions of others on a subject.
8. **Obtaining, evaluating, and communicating information:** It means obtaining and interpreting different information, identifying sources of error and defects in the methods used, obtaining and evaluating several information, and communicating information in different new ways.

The study (Scannell, 2019) aimed to examine the impact of implementing a ninth-grade physics curriculum in light of the (NGSS) standards on teachers' beliefs and practices about teaching science, and to determine whether this new approach facilitates teachers' beliefs and practices in the classroom. The results indicate that implementing pattern physics positively impacted teachers' confidence in teaching scientific and engineering practices in the (NGSS) standards, and that professional development provided teachers with new and multiple opportunities to engage with the curriculum in the role of the student and discuss with colleagues, which is a very important effect that is consistent with three-dimensional teaching according to the (NGSS) standards. The teacher participants viewed the pattern sequence (physics, chemistry, and biology) as an appropriate sequence for the course, with strong

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agreement that the ninth-grade physics course needs to be designer to the needs of students, such as: additional support for students with minimal mathematics skills. The focus on three-dimensional learning (scientific and engineering practices, disciplinary core ideas, and cross-cutting concepts) had a significant positive impact on teaching practice.

The study (Smith and Nadelson, 2017) aimed to reveal the extent to which elementary science teachers practice the scientific and engineering practices of the (NGSS) standards in teaching using the blended curriculum. The study sample consisted of three teachers from the third, fourth and fifth grades. To achieve the purposes of the study, an observation card, a questionnaire and interviews were used as research tools. The results of the study showed that teachers partially and substantially applied many of the (NGSS) practices in their teaching, but at the same time they were unable to apply all eight practices. The study recommended the need to train teachers on the (NGSS) standards.

The study (Rogan-Klyve, 2016) aimed to investigate the characteristics and methods of teachers to provide students with the opportunity to participate in scientific and engineering practices. It also investigated the obstacles to implementing science standards and negotiating their feasibility with teachers. The study followed the descriptive analytical approach, and collected data using an observation card and personal interviews. The results of the study indicated the weakness of the practice of criticizing current scientific explanations by students, which negatively affects students' understanding of the nature of science and how it works. The study also revealed a large discrepancy in understanding the philosophy of science standards and methods of applying them, and recommended training teachers to understand them. The study recommended paying attention to the context in which teachers' practices are applied to enhance science standards practices.

Networked Professional Learning Community (NPLC)

Forming a networked professional learning community to support personalized learning is unique to the teacher. Some networked professional learning communities consist of teachers who teach the same content, while others may include teachers with diverse perspectives on teaching. Networked professional learning communities are built to support professionals in their networked professional learning goals, needs, and interests. The learning opportunities available in networked professional learning communities have led to tangible change in practice and student learning. This is because, unlike a one-size-fits-all workshop or conference, teachers engage in learning with other teachers worldwide, whenever they want, through social media networks. This type of professional learning has provided teachers with a means for authentic learning and a community that engages, builds relationships, and transforms teacher practice (Trust, Carpenter, and Krutka, 2017).

The study (Pan and Chen, 2023) aimed to explore how teachers' collaboration in networked professional learning communities affects their beliefs and behaviors in professional learning, and further influences their acceptance of change. First, the results indicated that the intervention of a professional learning community with networked professional learning communities had a significant positive effect on teachers' acceptance of change. Second, teachers' collaboration in networked professional learning communities also showed a significant effect on their beliefs and behaviors regarding professional learning. Third, the program intervention, which uses practical professional learning activities, had a significant effect on teachers' tendency to achieve program goals. The results obtained from this study help develop strategies to support the implementation of the networked professional learning communities program.

The study (Prenger, Poortman, and Handelzalts, 2019) was conducted entitled the effects of networked professional learning communities, which considered teachers' professional learning as a crucial element in promoting the quality of education; as teachers' collaboration in professional learning communities can contribute to the effectiveness of professional development efforts. Professional learning communities have transferred in the past decade, from being within schools to being between schools. The effects of about (23) networked professional learning communities were examined in this study in the Dutch context, using a mixed methods approach; The results showed moderate positive effects on teachers' perceived satisfaction in both: advanced knowledge, skills and attitudes; and their application in practice. Considering the early stage of the development of these professional learning communities, teachers' participation in networked professional learning communities seems promising for enhancing their professional learning.

The study (Casey, 2017) aimed to gain insight into teachers' perceptions of a networked professional development program for (K-2) teachers to better prepare them to teach using the (NGSS) standards through networked professional learning communities. The program was designed to improve teacher practice, support teacher change, and foster professional development. The results of this study showed that teacher self-efficacy levels were positively affected by the training, and teachers sought out opportunities to be part of the networked professional learning community. The research findings on teachers' perceptions are expected to inform the design and implementation of networked professional development programs for teachers in the future.

Therefore, the effective implementation of three-dimensional learning requires that science teachers obtain the necessary training and support to integrate these practices into their teaching. Professional learning opportunities should focus on helping teachers understand the principles of three-dimensional learning, develop proficiency in using scientific practices in the classroom, and create engaging and authentic learning experiences for their students.

Training Needs for Science Teachers

As the educational landscape evolves, so do the methods and skills required for effective teaching. For science teachers, understanding science standards, engaging in three-dimensional learning environments, integrating scientific and engineering practices, and participating in a networked professional learning community are vital components of successful teaching.

– **Science Standards-Specific Training Needs:** Science standards emphasize a shift toward an inquiry-based, student-centered approach to science education. Teachers should receive professional learning on how to effectively implement these standards, ensuring they are able to guide students through inquiry-based, hands-on learning experiences (NGSS Lead States, 2013).

– **Three-Dimensional Learning Training Needs:** Teachers need training to develop comprehensive lesson plans that integrate the three-dimensions (practices, concepts, ideas), enabling learners to understand science in a more holistic way. Professional learning in this area should facilitate collaboration among teachers to design, evaluate, and enhance their instructional practices (DeLaurentis, 2021).

– **scientific and Engineering Practices Training Needs:** Implementing scientific and engineering practices in the classroom requires teachers to be well-versed in inquiry-based learning, problem-solving, and analytical skills. Professional development should provide teachers with strategies to effectively integrate these practices into their lessons and assessments (NRC, 2012).

– **Training needs for the Networked Professional Learning Community:** Collaboration in the Networked Professional Learning Community provides a collaborative platform for science teachers to share best practices, engage in reflective dialogue, and track continued learning in their teaching methodologies. Training should provide a practical approach to creating and sustaining these networks, including how to leverage technology for online collaboration and professional engagement. Emphasizing the role of mentorship within networks can enhance teachers' skills and confidence (Darling-Hammond, Hyler, and Gardner, 2017).

In order to prepare students for success in STEM fields and foster a deeper understanding of science concepts, it is essential that science teacher training evolves to meet these needs. By focusing on implementing science standards, promoting three-dimensional learning practices, effectively implementing scientific and engineering practices, and leveraging the Networked Professional Learning Community, we can develop a generation of scientifically literate individuals who are prepared to meet the challenges of tomorrow. Each area of training is interconnected, facilitating a comprehensive approach to significant educational improvements. Teachers are encouraged to pursue continuous learning in these areas not only to advance their teaching, but also for a fruitful future in science education.

Research problem

The research problem is as follows:

– The sense of the research problem emerged through the researcher's review of many related studies, including (Fadl, 2021) (Kamel, 2022) (Hamzi and Muhammad, 2022) (Abdullah and Saif, 2020); where the results of these studies confirmed the importance of networked professional learning for the teacher, the role of networked professional learning communities as a constructive approach to developing a culture of networked professional development for the teacher, the importance of planning learning according to science standards, and emphasizing scientific and engineering practices among students.

– Most previous research has addressed the problem of science teachers' needs for training in scientific and engineering practices either qualitatively or quantitatively. Therefore, there is a need for a more complete understanding by comparing and synthesizing both qualitative and quantitative data.

– By following global trends in teaching research and reports issued by bodies and institutions, such as the report published by the National Science Teachers Association (NSTA), it indicated the importance of the role of teachers, and the responsibility that falls on them in understanding these standards and applying them in their teaching practices; so that they can apply the vision of the (NGSS) standards in the field.

– Through the researcher's follow-up of Egypt's Vision 2030, which focused on professional development and continuous training for teachers, as the teacher faces various variables in his career that he cannot keep up with except by acquiring the experiences that qualify

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him, and this is done through sustainable professional development.

– Future trends also indicate that the networked professional learning community will impose itself on educational systems; so that the educational institution becomes a vision for learning and not a place for it, which means that fundamental changes will occur in the learning process.

Research questions

The current research was identified in an attempt to answer the following questions:

1. How do science teachers describe their beliefs about scientific and engineering practices?
2. To what extent do students engage in activities related to scientific and engineering practices in science classrooms and laboratories?
3. To what extent do you, as a science teacher, implement activities related to scientific and engineering practices in science classrooms and laboratories?
4. How do you think students benefit from learning scientific argumentation?
5. In your opinion, how important is it for students to learn scientific argumentation in relation to the topics you think students should learn in science?
6. What is the appropriate networked professional learning opportunities for teaching scientific and engineering practices?
7. What are the training needs of science teachers to teach scientific and engineering practices in science classes through the network professional learning community?
8. To what extent do the qualitative and quantitative results converge?

Purpose of the study

“The study aims to determine the training needs of science teachers for teaching scientific and engineering practices within a network professional learning community. A convergent mixed methods design will be employed to analyze and discuss the similarities and differences between quantitative and qualitative data. This design will involve collecting survey data from (17) science teachers to gather both quantitative and qualitative insights. The purpose of collecting both types of data is to allow for comparison and integration, leading to a more comprehensive understanding of the issue than could be achieved by using either method alone”

Research assumptions

– Promoting science teacher teaching practices is reflected in the quality of learning outcomes.

– Building networked professional development programs for science teachers using networked professional learning communities requires identifying the strengths and weaknesses in teacher performance through their understanding to apply the (NGSS) standards and their opinions, ideas and beliefs about scientific and engineering practices in order to determine their needs for the networked professional learning community.

– Effective learning through networked professional learning communities requires a shared vision and goals, a collaborative culture, communication and knowledge exchange; to support the science teacher’s implementation of the (NGSS) standards.

– Building lessons in light of the (NGSS) standards meets the learner’s needs in promoting scientific and engineering practices.

– The development of educational research depends on the suitability of the research design, data processing methods, research tools and the accuracy of its results.

Research terminology

Networked Professional Learning Communities (NPLCs): (Prenger, Poortman, and Handelzalts, 2019) defines networked professional learning communities as “communities consisting of teachers who use digital platforms and tools to connect, communicate, and collaborate with each other on a regular basis for the purpose of professional development, knowledge sharing, collaboration, and problem solving; to support continuous learning and improve teaching practice.”

The researcher defines it procedurally: Groups of teachers who come together to collaborate, learn, and improve their teaching practices through the use of digital technologies. These communities are formed on the basis of common interests or goals for the purpose of networked professional development for science teachers.

– Scientific and engineering practices: The behaviors that scientists and engineers use in the real world, and students are expected to identify problems by identifying criteria and constraints for acceptable solutions, finding and assessing multiple solutions, building and testing prototypes, and enhancing the solution (NRC, 2015).

The researcher defines them procedurally: Behaviors that students need to develop in order to collaborate in scientific research and engineering design, which are: asking questions (for science) and defining problems (for engineering), developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations (for science) and designing

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solutions (for engineering), engaging in argument from evidence, obtaining, assessing, and communicating information.

Delimitations

– Studying the opinions, ideas and beliefs of science teachers about scientific and engineering practices in order to determine their needs for the network professional learning community.

– The research sample included a group of (17) science teachers in schools (government, private and official language schools) across different educational administrations in the Arab Republic of Egypt.

– Applying the research Instrument electronically via social media sites.

– Analyzing and interpreting the data according to the opinions and ideas to be explored using codes.

Research Instrument

The current research relied on a questionnaire to investigate the opinions, ideas, and beliefs of science teachers about science and engineering practices in order to determine their needs for a networked professional learning community. The questionnaire examines the teaching described and observed by teachers in classrooms about science and engineering practices in science standards; to provide some key features of professional learning that may support teachers for enhancing their understanding, goals, and classroom teaching about these practices.

The questionnaire was adapted from its foreign version that sought to enhance science teachers' understanding of scientific and engineering practices (Kawasaki, 2015).

The questionnaire was translated, the translation was reviewed by a specialist, and the questionnaire was presented to arbitrators to ensure its validity.

This Instrument includes a set of questions organized into four parts:

- **Part One:** Includes a description of what the science teacher believes about the eight scientific and engineering practices.
- **Part Two:** Classroom instructional practices, by placing only one mark in each row; to express the frequency with which students in your class participate in specific types of activities, and the frequency with which the following instructional practices are used in your class.
- **Part Three:** The value of scientific argumentation, by describing your ideas about the importance, value, and benefit of scientific argumentation for your students.
- **Part Four:** Networking professional learning opportunities, by choosing the type of networking professional learning opportunity that may support your needs as you transfer to science standards.

The following Table (1) shows the response to the questions on the Likert scale with the method of correcting them, while the multiple-choice question is corrected as follows (each choice in the multiple-choice question equals 1).

Table (1): Method of correcting teachers' questionnaire questions on a Likert scale

	Part Two: Classroom instructional Practices						
Q1 Q2	Scale	Never	Several times a year	Several times a semester	Several times a month	Several times a week	Daily or almost daily
	Correction	1	2	3	4	5	6

A grading scale is used that shows the average and its corresponding level, and the scale includes six levels

The researcher verified the content validity of the questionnaire after translation and used Cronbach's alpha coefficient; to verify the reliability by using the statistical analysis program (SPSS, V.22), the overall reliability coefficient of the questionnaire (0.88), which is a high value; indicating the reliability of the questionnaire and thus the validity and reliability of its results.

The electronic questionnaire link was sent to the sample of teachers and (17) responses were received electronically.

Sampling and research population

It included a group of (17) science teachers out of (106) science teachers; where **the Maximum Variation Sample** was chosen as a strategy for **Purposeful Sampling**; to present the phenomenon from more than one perspective, so this strategy makes the researcher form his sample from different respondents in terms of characteristics.

The following table (2) shows the characteristics of the sample members expressed in terms of the number and percentage representing each category

Table (2): Characteristics of the sample members of science teachers (N= 17)

Variable	Category	Number	Percentage
Gender	Males	4	23.53%
	Females	13	76.47%
Years of Experience	1-5	7	41.18%
	6-10	3	17.65%
	11-15	1	5.88%
	16-20	2	11.76%
	21-25	1	5.88%
	26-30	1	5.88%
	More than 30	2	11.76%
Academic Qualification	Bachelor's degree	7	41.18%
	Postgraduate studies in Education	10	58.82%

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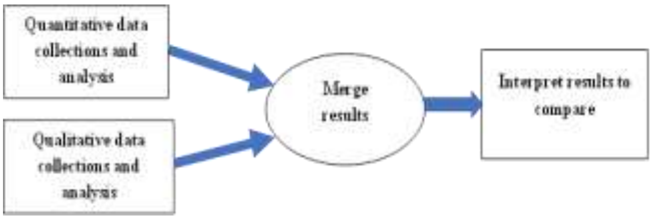
Research Design

The current research relied on **the mixed research approach** to investigate the opinions, ideas and beliefs of science teachers about scientific and engineering practices in order to determine their needs for the networked professional learning community (Tashakkori, Johnson, and Teddlie 2021). **Convergent Design** was chosen; where one stage is used to collect data, during which qualitative and quantitative data are collected and analyzed separately but simultaneously, then the results are combined during the research interpretation stage, and equal priority is given to both types of research; to develop a more comprehensive understanding of the phenomenon and confirm the results (Creswell and Plano Clark, 2018).

The following Figure shows Qualitative, quantitative, and mixed methods approaches:



Figure(1) Qualitative, quantitative, and mixed methods approaches (Creswell and Creswell, 2023)

Research Procedures

- Translate the questionnaire, and review the validity of the translation by a specialist.
- Send an electronic copy to teachers via social media sites.
- Respond to teachers' questions and inquiries about any difficulty in the questionnaire.
- Collect and organize data using Microsoft Excel spreadsheet program.
- Analyze questionnaire results, and interpret the teachers' responses.

Data analysis and interpretation

"I utilized a mixed methods approach to combine quantitative and qualitative data analysis and interpretation, which enhanced the findings from both types of data. In my convergent design, I integrated the data by creating a table that shows results from both datasets, referred to in the literature as a joint display. This visual tool allows for easy comparison of the two sets of results. One format for this joint display is a side-by-side table that depicts qualitative themes next to quantitative statistical results. Additionally, I included a final column to emphasize the differences and similarities between the qualitative themes and the statistical findings. This method is commonly used in convergent designs, helping readers understand how the qualitative and quantitative results correspond or diverge (Creswell and Plano Clark, 2018).

The researcher followed the open coding approach by reading the collected responses and taking initial notes focusing on recurring themes or important ideas to identify the codes; which helped the researcher to know the characteristics of each code and to know the most recurring codes (Sebastian, 2019). The codes and their repetitions and the corresponding the teachers' responses were monitored in Tables (3) and (6):

- **First: Scientific and engineering practices (Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8).**

The following Table (3) shows the teachers' responses to the scientific and engineering practices questions in the questionnaire:

Table (3): The teachers' responses (N= 17) to the scientific and engineering practices questions in the questionnaire

Q:1 Please describe the practice of asking questions (for science) and identifying problems (for engineering).			
The code	The description	The teachers' Responses	The repetition
Research questions	Ask testable questions/problems.	Science teachers develop students' ability to ask precise and specific questions, propose testable solutions to a problem that can be answered through experimentation and evidence, and then choose the best solutions to solve that problem.	**8**
Purposes of research questions	Questions should lead to additional practice (investigation, research, further analysis and interpretation).	The teacher begins by discussing with the students, then encourages them to ask questions about the phenomenon by carrying out a set of investigative activities.	**5**
Questions type	Questions are driven by critical curiosity about the world, models, theories, or investigations.	Students describe phenomena around the world and interpret solutions by asking and answering questions to solve a problem or design solutions to that problem.	**5**
Q2: Please describe your practice of .developing and using models			
The code	The description	The teachers' Responses	The repetition
Model repres	Models should be	Developing models helps students	**8**

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entation	representations of a scientific phenomenon.	understand and explain phenomena that are difficult for them to imagine, such as designing a model of the atom or designing a model of the solar system.	
Modeling	Modeling is an iterative process of evaluation and review.	Students build and evaluate models to identify strengths and weaknesses and then improve these models.	**9**
Q3: Please describe your practice of planning .and carrying out investigations			
The code	The description	The teachers' Responses	The repetition
Collaboration	Students have opportunities to participate in investigations led by the teacher or on their own.	Science teachers explain to learners the importance of good planning and careful implementation of science experiments. Conducting science experiments requires the ability to develop questions and inquiries through which observations can be interpreted, questions answered, and hypotheses tested.	**10**
Purposes of scientific investigations	Investigations identify the purpose of the investigation, predict outcomes, and plan the course of action that will provide the best evidence to support their conclusions.	Scientific investigations involve monitoring data and determining variables in scientific experiments, and thus planning and conducting a systematic investigation to study the phenomenon. Engineering investigations involve obtaining the necessary data for research variables that help in testing the proposed design.	**8**
Q4: Please describe the practice of analyzing . and interpreting data			
The description The code		The teachers' Responses	The repetition
Data representation	Convert data into graphical representations and visualizations, and perform statistical analysis to uncover patterns and relationships	Students use tables, statistical data, graphs, and statistical analysis to identify graphical characteristics and relationships.	**7**

	.		
Sources of error	Students' ability to identify sources of error, e.g. experimentation.	Science teachers help learners handle data correctly. Data from scientific experiments should be presented clearly in order to reveal relationships between different variables.	**6**
Sources of primary and secondary data	The results obtained are interpreted to answer the questions posed at the beginning, and they are analyzed, evaluated, and the strengths and weaknesses are identified, and the data is modified and claims are made. Analyzing the data collected about a problem helps to understand its meaning through a set of tools that determine the validity and reliability of this data, which helps to interpret the results. Students have opportunities to analyze and interpret primary data sources (i.e. make a claim, develop a model, or explain a phenomenon) and secondary data sources (i.e. confirm/contradict results/claims/models).		**5**
Q5: Please describe the practice of using .mathematics and computational thinking			
The code	The description	The teachers' Responses	The repetition
Purposes of mathematics	Use mathematics to make quantitative predictions and identify patterns and relationships.	In science, mathematics and computational thinking are used to predict the behavior of physical systems through experimentation and to find correlations between physical variables. In engineering, mathematics and computational thinking are used to represent principles and relationships during the design process.	**9**
mathematics Understanding	Apply procedural and conceptual understanding of mathematics to scientific problems.	It depends on the integration of science with mathematics, the use of mathematics to solve scientific problems, and the presentation of scientific models that explain phenomena.	**7**
Purposes of digital tools	Use digital tools, such as computers and calculators, to handle large data sets.	Mathematics is used in the statistical analysis of data, thus arriving at logical explanations for a phenomenon, and arriving at the best possible solutions for it.	**3**
Q6: Please describe the practice of			

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constructing explanations (for science) and .(designing solutions (for engineering			
The description The code		The teachers' Responses	The repetition
Interpretations building	Constructing scientific explanations from empirical evidence**.**	The goal of science is to construct theories and explanations about the physical world. A theory becomes acceptable when supported by experimental evidence and scientific explanations. The goal of engineering design is to follow a systematic solution to problems based on scientific knowledge and designed models; in order to obtain several solutions and choose the best solution according to the design**.**	**8**
Application of interpretations	Applying scientific explanations to understand scientific phenomenon**.**	Science teachers explain to learners that scientific theories are explanations of the phenomena around us in order to understand them more accurately**.**	**6**
Scientific evidence and explanations	Using and justifying evidence in scientific explanations**.**	Scientific explanations do not come out of nowhere. They are based on evidence, proof, and many experiments, and are based on abundant information that has been subjected to scrutiny by scientists**.**	**4**

Q7: Please describe the practice of engaging in .argument from evidence			
The code	The description	The teachers' Responses	The repetition
Scientific arguments	Evaluate others' arguments**.**	Students draw arguments and evidence to identify strengths and weaknesses and choose the best ways to explain the problem and explain natural phenomena**.**	**10**
Scientific argumentation	Build/develop/defend scientific claims using data and evidence**.**	In science, students use scientific argumentation to explain how they have built their claims about a phenomenon, defending their claims with a solid foundation of data and evidence. In engineering, engineers use scientific argumentation to discover the best possible solution to a problem. Scientific argumentation is used throughout the design process, and evidence based on design test data is compared**.**	**5**
Claims and scientific evidence	Evidence justification for scientific claims/arguments.	In this method, students rely on explaining phenomena through scientific claims supported by evidence to prove the validity of their explanations of scientific phenomena**.**	**3**

Q8: Please describe your practice of obtaining, .evaluating, and communicating information			
The code	The description	The teachers' Responses	The repetition
Scientific texts	Reading and producing scientific texts**.**	The teacher directs students to read, interpret and produce scientific texts with the aim of developing models and explanations, and directs them to evaluate sources of information and verify their validity**.**	**8**
Discussion	Participate in oral/written discourse on scientific topics**.**	Information and ideas are exchanged verbally through discussions with peers, through seminars or the Internet, or in writing from written texts, graphs, tables or charts**.**	**7**
Critical assessment	Critical evaluation of the merits and validity of scientific texts/arguments/discourse.	Science teachers explain to learners how to evaluate scientific information by subjecting it to critical thinking, examining the methodology used in terms of validity and reliability, and identifying areas of agreement and disagreement to arrive at that information**.**	**4**

The results of qualitative data analysis (QDA) table (3) for the teachers' responses around (SEP) questionnaire indicate that many teachers can describe (SEP) that aligned with the goals of (3-D) learning as the following:

– It is necessary to focus on developing students' abilities to participate in scientific and engineering

International Journal of Instructional Technology and Educational Studies (IJITES)
ISSN (Print): 2682-3918 - ISSN (online): 2682-3926
Volume5 / Issue3, August, 2024
DOI: 10.21608/ihites.2025.333355.1211

practices. In addition, the necessary to provide opportunities for students to cooperate, communicate and enhance their understanding through engineering design challenges.

- It is necessary to guide students in developing scientific practices to develop their abilities to think scientifically by encouraging students to ask meaningful questions and identify problems to develop their scientific research skills. Help students develop and use models as tools to represent complex scientific concepts and phenomena. Provide opportunities for students to plan and implement investigations to collect data and explore scientific phenomena. Provide opportunities for students to analyze and interpret data collected during investigations to draw meaningful conclusions. Provide opportunities for students to understand and solve complex scientific problems through the use of mathematics and computational thinking. Provide opportunities for students to develop the skills necessary to build scientific explanations and design solutions based on scientific evidence and principles. Promote scientific discourse by encouraging students to engage in evidence-supported arguments. Provide opportunities for students to access and evaluate scientific information and communicate their results effectively.
- It is necessary to guide students in developing engineering practices in science education to promote creativity, problem-solving skills, and collaboration among students by encouraging students to accurately identify and define engineering design problems. Provide opportunities for students to develop solutions by using their scientific knowledge and creative thinking skills to develop solutions to identified problems. Provide opportunities for students to improve their design solutions through iterative processes. Provide opportunities for students to direct the design process. Provide opportunities for students to direct design improvements. Provide opportunities for students to engage in scientific arguments and defend their design solutions based on scientific evidence. Provide opportunities for students to access and evaluate relevant information to inform their design solutions and communicate their ideas effectively.
- It is necessary that the steps of the scientific method should always be followed in order. In fact, scientific inquiry and engineering design are often cyclical and iterative. Researchers and designers may move back and forth between different steps based on what they are learning.

- **Second: Classroom instructional practices (Q1, Q2).**

The following table (4) shows the teachers' responses to question (1) regarding classroom instructional practices in the questionnaire:

Table (4): The teachers' responses (N= 17) to question (1) regarding classroom instructional practices in the questionnaire

Q1: To what extent do your students do each of the following in science classrooms and labs?								
phrase	Never	Several times a year	Several times a semester	Several times a month	Several times a week	Daily or almost daily	Arithmetic mean	Sample direction
	The repetition	The repetition	The repetition	The repetition	The repetition	The repetition		
Graphical representation of scientific data.	2	5	4	4	2	0	2.94	several times a semester
Generate their own questions about everyday phenomena.	1	6	4	3	2	1	3.12	several times a semester
Design their own experiments; to investigate a scientific phenomenon individually or in groups.	3	3	3	5	1	2	3.24	several times a semester
Analyze secondary data they find in books, online, or elsewhere.	5	3	5	1	2	1	2.71	several times a semester
Explain their ideas to each other in small groups or to the whole class.	0	5	4	3	3	2	3.59	several times a month
Identify/discuss evidence that supports a scientific theory.	2	6	5	2	2	0	2.76	several times a semester
Using computer simulation to understand a scientific phenomenon.	2	5	5	3	2	0	2.88	several times a semester
Identify and collect evidence to support their claims about a scientific topic.	3	5	3	2	3	1	3	several times a semester
Develop their own interpretations from scientific data.	3	4	4	3	1	2	3.06	several times a semester
Analyze the primary data they collected themselves.	2	4	5	4	1	1	3.06	several times a semester
Generate questions about something they read in or out of	1	4	5	3	3	1	3.35	several times a semester

International Journal of Instructional Technology and Educational Studies (IJITES)
ISSN (Print): 2682-3918 - ISSN (online): 2682-3926
Volume5 / Issue3, August, 2024
DOI: 10.21608/ihites.2025.333355.1211

class.								
Use tables or graphs to support a scientific claim.	0	5	3	6	3	0	3.41	several times a semester
Calculating simple statistics from data (e.g., mean).	2	4	5	4	2	0	3	several times a semester
Conduct an experiment from a laboratory book individually or in groups.	0	5	5	2	4	1	3.47	several times a semester
Revise a model or interpretation they have already provided.	2	4	5	4	0	2	3.12	several times a semester
Write a lab report; to share their results from an experiment or investigation.	3	4	4	4	0	2	3	several times a semester
The general arithmetic mean and sample trend for question (1) in the classroom instructional practices in the questionnaire							3.11	several times a semester

According to the qualitative data analysis (QDA) table (4) for the teachers' responses to question (1) regarding classroom instructional practices, we find that the general arithmetic mean is (3.11) and the general sample trend on the statements is several times in the semester, which are low rates; indicating the weakness of including scientific and engineering practices for science teachers during teaching.

The following table (5) shows the teachers' responses to question (2) regarding classroom instructional practices in the questionnaire:

Table (5): The teachers' responses (N= 17) to question (2) regarding classroom instructional practices in the questionnaire

Q2: To what extent do you, as a science teacher, do all of the following in science classrooms and laboratories?								
phrase	Never	Several times a year	Several times a semester	Several times a month	Several times a week	Daily or almost daily	Arithmetic mean	Sample direction
	The repetition	The repetition	The repetition	The repetition	The repetition	The repetition		
Ask students to explain or justify a scientific claim they have made.	0	6	3	4	3	1	3.41	several times a semester
Use a chart, table, or graph during teaching to illustrate a new scientific topic.	0	3	5	6	3	0	3.53	several times a month
Discuss with students how to interpret quantitative data from an experiment or investigation.	1	2	4	5	3	2	3.76	several times a month
Teach a lesson on how to write scientific results in a lab report or scientific article.	0	6	2	5	1	3	3.59	several times a month
Provide students with a range of questions that they can choose from to investigate themselves.	0	2	5	7	2	1	3.71	several times a month
Teaching a lesson in interpreting statistics or quantitative data.	0	7	5	2	2	1	3.12	several times a semester
Ask students whether they agree or disagree with their classmates' explanation of a scientific phenomenon.	1	2	6	4	2	2	3.59	several times a month
Discuss appropriate procedures for conducting a scientific experiment with students.	1	4	2	5	3	2	3.65	several times a month
The general arithmetic mean and sample trend for question (2) in the classroom instructional practices in the questionnaire							3.55	several times a month

According to the qualitative data analysis (QDA) table (4) for the teachers' responses to question (2) regarding classroom instructional practices, we find that the general arithmetic mean is (3.55) and the general sample trend on the statements is several times a month, which are low rates; indicating the weakness of including scientific and engineering practices for students during the science teaching and learning processes.

The results of (QDA) tables (4) and (5) for the teachers' responses regarding classroom instructional practices indicating the following interpretations:

– At the heart of scientific and engineering practices lies the ability to ask questions, develop and use models, integrate arguments from evidence, and explore comprehensive concepts that link different scientific disciplines. Many teachers still rely heavily on traditional educational methods that emphasize rote memorization rather than inquiry-based learning. This implementation gap may stem from a lack of confidence in their ability to teach these practices, insufficient professional learning opportunities, limited resources, or restrictive curricula that do not prioritize inquiry-based methods.

– To address these weaknesses, a multifaceted professional learning community specifically

International Journal of Instructional Technology and Educational Studies (IJITES)
ISSN (Print): 2682-3918 - ISSN (online): 2682-3926
Volume5 / Issue3, August, 2024
DOI: 10.21608/ihites.2025.333355.1211

designed to meet the needs of science teachers is essential. This program should emphasize collaborative learning, allowing teachers to share best practices and strategies for integrating scientific and engineering practices into their curricula. Workshops could include:

✓ **Hands-on experiences:** Providing teachers with opportunities to directly engage in science experiments and engineering design challenges can demystify these practices and boost their confidence in delivering them to students.

✓ **Curriculum alignment:** Guidance on how to align existing curricula with science standards or similar frameworks can help teachers understand how to seamlessly integrate content and practice.

✓ **Integrated technology:** Leveraging new technology tools, such as simulation software and online collaboration platforms, can enhance teaching and learning and enable teachers to create dynamic and interactive classroom environments.

✓ **Peer mentoring programs:** Creating mentoring programs where experienced teachers coach those who are new to modeling science practices can foster a supportive community that emphasizes ongoing growth and innovation.

– Empowering teachers is an ongoing process. By creating a network of resources, such as: online forums, feedback mechanisms, and networked professional learning communities, teachers will be able to access the tools they need to develop their instructional practices, share experiences, and adjust their strategies in response to students' needs.

o Third: The value of scientific argumentation (Q1, Q2).

The following table (6) shows the teachers' responses to the questions on the value of scientific argumentation in the questionnaire

Table (6): The teachers' responses (N= 17) to the questions on the value of scientific argumentation in the questionnaire

Q:1 How do you think students benefit from learning scientific argumentation?			
The code	The description	The teachers' Responses	The repetition
Building scientific knowledge	Engaging students in scientific arguments through scientific discussion to build scientific knowledge.	Scientific arguments helps students exchange information with each other, correct misinformation, and build scientific knowledge.	**8**
Engage in discussion	Students' ability to talk about scientific concepts; thus providing opportunities to explain these concepts.	It helps students explain different scientific phenomena around us and provide evidence for their explanation of that phenomenon.	**5**
Collaboration	Students' ability to think critically, understand deeply and present scientific arguments in a logical and coherent manner, orally or in writing, allowing for full collaboration in society.	Helps students think scientifically, defend/criticize/enhance claims or explanations of a phenomenon, communicate with others to understand different points of view about a problem, and arrive at logical solutions to that problem in the presence of evidence based on investigations.	**5**

Q2: In your opinion, how important is it for students to learn scientific argumentation in relation to the topics you think students should learn in science?			
The code	The description	The teachers' Responses	The repetition
Different Scientific Ideas	Students discuss different ideas for research questions.	Helps students develop their thinking skills about a phenomenon.	**6**
Interpreting Data	Students discuss ways of interpreting data.	Helps students explain scientific phenomena and conduct scientific experiments based on scientific explanations and reasons.	**8**
Claims and Evidence	Students discuss claims and supporting evidence provided by others.	Helps students develop claims, and support the claim with evidence through investigation.	**5**

The results of (QDA) table (6) for the teachers' responses regarding the value of scientific argumentation indicating the following interpretations:

– Scientific argumentation is a crucial practice that students must develop in the field of education. This practice includes the ability to critically analyze and evaluate scientific information, communicate ideas effectively, and participate in constructive discussions.

– Engaging in scientific argumentation provides students with opportunities to develop and enhance their cognitive skills. By analyzing scientific information, students can apply critical thinking and problem-solving strategies. They learn to evaluate evidence, consider multiple points of view, and draw logical conclusions. This practice is essential for scientific literacy and enables students to make informed decisions based on evidence rather than personal beliefs or biases.

– Scientific argumentation also enhances effective communication and presentation skills. Students are encouraged to express their arguments and defend their points of view using clear and concise language. Through scientific discussions, they learn to express complex ideas in a coherent manner and adapt their language to different audiences. These communication skills can be transferred to other areas of life as well, enabling students to become successful

International Journal of Instructional Technology and Educational Studies (IJITES)
ISSN (Print): 2682-3918 - ISSN (online): 2682-3926
Volume5 / Issue3, August, 2024
DOI: 10.21608/ihites.2025.333355.1211

interactive contributors in their professional and personal lives.

- Scientific argumentation often takes place within a collaborative learning environment, allowing students to work together to formulate hypotheses, conduct experiments, and evaluate data. This collaborative approach promotes teamwork and collaboration, helping students develop essential social skills. They learn to listen effectively, respect diverse viewpoints, and engage in constructive, evidence-based discussions. By working collaboratively, students become more confident in expressing their ideas, learning from each other, and developing a deeper understanding of scientific concepts.
- Scientific argumentation is a motivational tool for students, as it encourages active collaboration and engagement in the learning process. When students are given the opportunity to analyze and discuss scientific concepts, they develop a sense of ownership and agency in their learning. This intrinsic motivation leads to increased curiosity, interest, and enthusiasm for science. By actively building their knowledge through argumentation, students are more likely to retain information and apply it in real-world contexts.
- Scientific arguments play a crucial role in promoting scientific literacy among students. They help them understand the nature of science, the process of investigation, and the importance of evidence-based reasoning. In a world where scientific advances are shaping our society, it is essential for students to possess these scientific literacy skills. Scientific arguments provide them with the ability to critically evaluate scientific claims, understand the implications of scientific research, and make informed decisions that contribute to societal progress and well-being.
- Integrating scientific arguments into the classroom requires careful planning and implementation. Teachers can use a variety of strategies to promote effective discussion. First, they can create a supportive classroom culture that encourages respectful dialogue and active collaboration. Teachers can design inquiry-based activities that encourage students to make claims, present evidence, and engage in refutation.
- Additionally, teachers can provide support and guidance to support students' argumentation practices. This can include teaching students how to identify reliable sources of information, evaluate evidence, and construct logical arguments based on scientific principles. Interactive technologies, such as online platforms or virtual simulations, can be used to provide additional opportunities for argumentation practice.

- **Fourth: Networking professional learning opportunities.**

The following table (7) shows the teachers' responses to the question about networking professional learning opportunities in the questionnaire:

Table (7): The teachers' responses (N= 17) to the question about networking professional learning opportunities in the questionnaire

Q1: What type of networking professional learning opportunity might ?support your needs as you transition to the NGSS						
	Engage in "model lessons" in light of NGSS	Learn instructional strategies to support NGSS	read NGSS	design lesson	Time to plan (individually)	Time to plan (with my colleagues)
The repetition	7	6	2	2	0	0
	%41.18	%35.29	%11.76	11.76 %	%0	%0

The results of table (7) that show the teachers' responses to the appropriate networked professional learning opportunities for teaching (SEP) indicating the following interpretations:

As teachers adapt to the science standards, it is essential to provide them with the appropriate type of professional learning opportunities. One effective way to support teachers during this transition period is through communication and professional learning initiatives that focus on "model lessons" and collaborative planning.

When it comes to implementing the science standards, teachers prefer to participate in "model lessons" rather than simply learning instructional strategies. There are several reasons why this approach is particularly effective: Model lessons provide a concrete example of how to implement the science standards in the classroom. Teachers can observe how lessons that align with the new standards are organized. Model lessons demonstrate how to integrate the three- dimensions of the science standards: scientific and engineering practices, disciplinary core ideas, and crosscutting concepts. By participating in model lessons, teachers can gain confidence in their ability to implement the new standards effectively.

To fully support the science standards, it is essential that teachers take the time to review and read the standards themselves. This process allows teachers to: Become

International Journal of Instructional Technology and Educational Studies (IJITES)
ISSN (Print): 2682-3918 - ISSN (online): 2682-3926
Volume5 / Issue3, August, 2024
DOI: 10.21608/ihites.2025.333355.1211

familiar with the structure and content of the standards. Identify the core concepts and practices that students are expected to master at each grade level. Understand how the standards build on each other from year to year. Identify opportunities for interdisciplinary connections and real-world applications.

– In addition to model lessons and reading the standards, teachers can benefit greatly from engaging in lesson study to design their instruction to the specific needs and interests of their students. Reflect on their instructional practices and identify areas for improvement. Share ideas, resources, and best practices with each other. Develop a shared understanding of the science standards and how to implement them effectively. Identify opportunities for interdisciplinary collaboration and project-based learning. Provide feedback and support to each other as they work to enhance their instructional practices.

- **Conclusions**

– The results suggest that there were varying degrees of alignment between the teachers' described and implemented classroom instruction, and between their described and the goals of three-dimensional learning.

– The results indicate that there is a gap between describing scientific and engineering practices and implementing them in the classroom; although teachers are able to describe what each scientific and engineering practice means, the rate of implementation of these practices in science classrooms is weak.

– The researcher believes that the difficulty teachers faced in activating these practices arose from teachers' misunderstanding and lack of alignment with the goals of science standards.

– While there are many benefits to integrating scientific and engineering practices into science education, there are also challenges that teachers may face. One common challenge is the lack of time and resources to fully implement these practices in the classroom. Teachers may find it difficult to find time to plan and conduct hands-on investigations, or they may not have access to the necessary materials and equipment.

– Another challenge is the need for professional learning and support for teachers to effectively integrate scientific and engineering practices into their teaching. Teachers may need training on how to implement inquiry-based learning, facilitate group work, and assess students' understanding of scientific concepts. Without adequate support, teachers may struggle to effectively integrate these practices into their teaching.

– Teachers emphasized the importance and benefit of scientific argumentation for students through their opinions, ideas, and beliefs about the value of scientific argumentation; it is the core of many practices in the science standards, by enhancing cognitive skills, effective communication and presentation skills, collaborative learning, motivation and engagement, and promoting scientific literacy.

Before engaging in any professional learning community, science teachers need a deep understanding of the science standards. They must become familiar with the structure, content, and vision of the standards. A clear understanding of the science standards system will allow teachers to align their teaching and assessment practices with the intended learning outcomes.

Science teachers need a strong foundation in the content areas they teach, as well as a deep understanding of scientific and engineering practices. They should be well-versed in the principles of inquiry-based learning, data analysis, and the application of scientific and engineering knowledge. This knowledge will enable teachers to design and facilitate these practices effectively in the classroom.

Teachers need to possess the knowledge and pedagogical strategies that support the implementation of scientific and engineering practices. They should be equipped with instructional methods that promote student engagement, critical thinking, and problem-solving skills. In addition, teachers should be familiar with formative assessment techniques to measure student understanding and provide timely feedback.

Science teachers should have opportunities to collaborate and network to enhance their professional learning. The online professional learning community provides teachers with platforms to engage in meaningful exchanges with colleagues, share resources, and co-create instructional materials aligned with science standards. Collaborative environments foster collaborative learning experiences, allowing teachers to learn from and contribute to a larger community of practitioners.

Professional learning is an ongoing process. Science teachers need ongoing professional learning opportunities that align with the changing needs of their students and with science standards. By participating in online professional learning communities, teachers can stay abreast of the latest research, instructional strategies, and technological advances that can support the effective integration of scientific and engineering practices.

Collaboration is essential when it comes to implementing science standards effectively. By working together and sharing our expertise, we can create engaging, inquiry-based learning experiences that help our students develop a deep understanding of scientific and engineering practices.

As teachers transition to science standards, it is essential to provide them with networked professional learning opportunities that meet their specific needs. By engaging in "model lessons" based on science standards, learning instructional strategies to support science standards, reading science standards, and engaging in lesson study,

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Volume5 / Issue3, August, 2024
DOI: 10.21608/ihites.2025.333355.1211

teachers can gain the knowledge, skills, and confidence they need to effectively implement the new standards and support student learning.

The above results are consistent with a study (Rogan-Klyve, 2016) that found significant discrepancies between descriptions of science standards and their implementation methods. The study recommended training teachers to implement them in science classrooms. The study also recommended paying attention to the context in which teachers' practices are implemented to enhance science standards practices.

The previous results are consistent with the study (Kawasaki, 2015) which recommended some key features of professional learning that may support teachers for enhancing their understanding, goals and teaching in classrooms about scientific and engineering practices.

- **Recommendations**
  - Organize regular workshops where teachers can collaboratively develop interdisciplinary modules. These should involve real-world problems that require engineering knowledge for scientific inquiry. Encourage the use of digital platforms to share resources and ideas beyond geographic constraints.
  - Establish a peer-to-peer coaching system within the networked professional learning communities. Experienced teachers can mentor novice teachers, focusing on effective strategies for teaching scientific and engineering practices. This mentoring should include classroom observations, reflections, and feedback sessions using video recording technology for richer analysis.
  - Provide teachers with up-to-date resources that align with current standards within the networked professional learning communities, including lesson plans, assessment criteria, and relevant digital simulations. Update this resource regularly with contributions from participating teachers, ensuring that each member has access to cutting-edge scientific tools and information.
  - Encourage science teachers to identify problems in their classrooms and develop experiments aimed at solving them. Provide guidance on conducting practical research, documenting results, and sharing experiences during networked professional learning communities meetings. This hands-on approach nurtures a culture of continuous improvement.
  - Schedule monthly virtual seminars where participants can present case studies on effective practice, emerging trends in science education, or results from action research. Use discussion forums to sustain conversations and stimulate feedback on these topics throughout the month.

– Provide access to multidisciplinary experts to share insights on contemporary scientific challenges and their engineering solutions, thereby bridging the gap between classroom learning and professional application.

Create structured opportunities for teachers to self-reflect and receive feedback on teaching effectiveness. Encourage the use of assessments that go beyond traditional tests, and frame assessments around collaborative projects and assignments that highlight engineering practice.

Future research could examine how networked professional learning community (NPLC) can further enhance collaboration and resource sharing among science teachers.

Conduct a future research similar to the current study but using a larger sample of participants for the quantitative portion of the survey.

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