SCIENTIFIC METHOD

OBJECTIVES/RATIONAL

In research, the scientific method is used to acquire dependable information when solving problems, making responsible choices, and evaluating the impact of new discoveries on society. Students will apply the systemic approach of the scientific method to investigate and gain a better understanding of the problem

TEKS: 121.12 1A, 1B, 2A, 2B, 2C, 2D, 3A, 3B, 3C, 4B, 8A, 8B, 8C, 9B

TAKS ELA 1, 3, 4, 6
Mathematics 1, 10
Science 1

KEY POINTS

The scientific method is characterized by (1) order (2) control (3) empiricism (4) generalization and theoretical formulation.

The scientific approach to problem solving requires the application of order and discipline to instill confidence in the investigator's results. This requires the application of the scientific method, in which a series of systematic steps are followed to solve problems. It can be tested and the steps may be deleted, skipped or the order may vary. The steps may include the following:

(1) identification of the problem to be investigated
(2) review of existing literature and information concerning the problem
(3) formation of the hypothesis (Null and Alternate)/statement of purpose of study
(4) designing the experiment
(5) collection of data
(6) analyzing the data
(7) drawing conclusions
(8) replicating the investigation
(9) dissemination of results *Research is <u>useless</u> without this step

I IDENTIFY THE PROBLEM

The study should start with a research question that addresses what the researcher would like to know. The goal is to find an important one that is feasible. The research question, which the researcher will answer, is selected and refined into a problem statement. The problem must be researchable and able to be tested. The research should contribute new knowledge about the problem. Consideration must be given to the availability of methods to investigate the problem, the availability of participants/subjects for the study, constraints of time and money required for the study, as well as ethical implications of the research project.

Research questions often begin with a vague and general statement which must be narrowed down to a concrete, focused issue before the planning efforts begin. This may involve breaking down the original question into smaller parts and choosing a smaller portion of the original question to build a study around. Research question should be "FINER": feasible, interesting, novel, ethical, and relevant.

II REVIEW THE LITERATURE

To place the problem in the context of what is already known about the problem, the researcher reviews the scientific literature related to the problem, citing references to professional publications and journal articles which pertain to the problem.

The literature review will summarize the existing knowledge pertaining to the problem and will help the researcher learn more about the problem. The researcher then uses this information to predict the outcome of the research or formulate a hypothesis.

Significance

A good research question should pass the "so what" test. The answer should contribute to the present knowledge about the topic. This gives the study rationale. What is presently known about the topic, why is the research question important, and what type of answer might the research study provide? The researcher will cite existing research that is relevant and indicate the possible problems with that research and what question(s) remain. The researcher makes clear how the results of the study will resolve these uncertainties. The student may also find a study to replicate or a well-written study to use as a guide.

III FORM THE HYPOTHESIS

The hypothesis is the statement of the purpose of the study. Hypotheses are statements that predict a relationship between two or more variables that can be tested. The hypothesis may be stated as a **NULL HYPOTHESIS**: a statement which indicates that there is no difference between two groups after treatment or as an **ALTERNATE HYPOTHESIS:** a statement which indicates there is a difference between two groups after treatment or both.

Example of a null hypothesis: Children of handicapped parents perceive their body image the same way that children of non-handicapped parents do.

Example of an alternative hypothesis: Children of handicapped parents perceive their body image differently than children of non-handicapped parents.

Variables are concepts that are defined in a way so that variations may be observed and measured. Variables may be classified as several ways: independent variables, dependent variables, and controlled variables.

Independent Variables: The treatment or condition that is expected to produce the result or outcome. On a graph, the independent variable is placed on the horizontal axis.

Dependent Variable: The result or outcome that is expected to occur from a treatment. The change in the dependent variable is presumed to be caused by the independent variable. The dependent variable is observed, measured, and analyzed to detect changes caused by the independent variable. On a graph, the dependent variable is placed on the vertical axis.

Control Variable: The characteristic that is controlled by the researcher in order to reduce any impact this factor might have on the interpretation of the results. Controlled variables should not be allowed to change. Controlled variables are not shown on a graph.

Moderator Variable: A characteristic that influences the impact of the independent variable upon the dependent variable.

Extraneous Variable: Factors that produce uncontrolled, unpredictable impacts on the dependent variable. Extraneous variables may cause confusion if they are not controlled. They are contaminating factors that are a threat to the validity of the study.

Control of factors not relevant to the investigation is an essential element of the scientific method. The investigator must try to identify the factors and the effects of the factors not directly investigated in connection with the problem, and try to keep them from influencing factors identified in the study.

IV DESIGN THE EXPERIMENT

The experimental design defines the way that pertinent information will be gathered in order to answer the research question.

A. HISTORICAL – constructs the past in relation to the hypothesis
Tracing the history of anesthesia in the USA

B. QUANTITATIVE DESCRIPTIVE – systematically describes an area of interest
Uses strategies such as questionnaires or observational techniques to collect information about the characteristics of a person, group, or program.
Surveys, census studies.

C. DEVELOPMENTAL – investigates patterns and sequences as a function of time
Longitudinal study of a group over a number of years or a cross-sectional study investigating changing patterns by sampling groups at different ages or levels.

D. CASE AND FIELD – studies the background, current status, and environmental interactions of a given social unit (an individual group…..)
C*ase histories of a group of teens on probation for drug abuse*

E. CORRELATIONAL – investigates the extent to which variations in factor correspond with variations in other factors
Study of student success in college based on patterns between college grades and selected high school variables

F. CASUAL-COMPARATIVE – investigated cause and effect relationships by observing an existing consequence and looking back through data for a possible cause.
Identify factors related to high school drop-out rates using data from records over the past en years

G. TRUE EXPERIMENTAL – investigates cause and effect relationships by exposing one or more experimental groups to one or more treatments and comparing the results to control groups not receiving the treatment (must be random). *Investigate the effectiveness of three different teaching methods to first grade students using random assignments of students and teachers*

H. QUASI – EXPERIMENTAL – approximates the true experimental in a limited setting. Researcher must understand thoroughly the compromises which exist that may affect the internal and external validity of the design
Attempt to get factors where only partial control is possible

I. ACTION – develops new skills or new approaches or solves problems with direct application to a setting
In-service training program to help teachers develop new skills in facilitating class discussions

All of the terms relating to the study must be carefully defined so there is no question about what the researcher means. The methodology defines the way that information or data will be gathered in order to answer the research question or hypothesis. This includes details about the selection of subjects who will participate in the study, and description of the data collection procedures and techniques. Plans for analysis of the data should also be included. Limitations of the study are included to identify particular aspects of the study over which the researcher has no control.

The scientific process is usually considered to be the highest form of human knowledge. Questions involving morality, complex social and psychological phenomena are hard to investigate because of the problems involved in measuring. When the study requires human subjects, constraints to protect them often pose added restrictions. It is vitally important that the investigator assures the protection of the rights of the study subjects as well as conform to the policies and procedures of the institution they are associated with.

V. COLLECT DATA

Record data, information, observations, and measurements accurately in a **logbook**. This step is necessary for reproducibility and to adequately test the hypothesis. Measurements should be accurate and precise. Information and data should be relevant to the stated research problem and recorded on tables, flow charts, concept maps, as notes, drawings, or diagrams.

VI. ANALYZE THE DATA

Analyze the data through graphs (bar, line, pie or circle) and statistics to determine relationships between variables and to find sources of error. The scientific method is also characterized by empiricism. The evidence gathered to generate new knowledge must be rooted in objective reality and must have been gathered through the human senses directly or indirectly.

VII. DRAW CONCLUSIONS

The conclusion should be based on the experiment and address the hypothesis. It should be VALID (based on the evidence) and RELIABLE (repeatable). The conclusion may either accept the hypothesis or reject the hypothesis. It is perfectly acceptable to reject the hypothesis. Many times scientists will have to reject their hypothesis based on the data they have collected and analyzed.

The scientific method is characterized by generalization. This means that the investigator does not use the scientific method merely to understand isolated events but must also be able to apply the results to a broader setting. The kinds of generalizations that result often assist in the development of new scientific theories and provide explanations and predictions of future events.

VIII. REPLICATE THE STUDY – either multiple trials or multiple set-ups

IX. DISSEMINATE THE RESULTS

After analyzing the data in relation to the research problem, the researcher will formulate conclusions, discuss them, and relate these conclusions to relevant present knowledge. The researcher will also cite implications of the research and suggest areas for further study. The researcher will target an audience who will benefit from the information the study offers. Taking into consideration the needs of the audience, the researcher will communicate the study as clearly as possible by submitting a paper to a suitable professional journal and/or presenting the results of the study at a professional conference. Without the dissemination of results – research has no useful purpose!

http://www.visionlearning.com/myclassroom/courses/NSC107_Carpi_index.htm

- **Choose:** 1-Scient. Method

http://phyun5.ucr.edu/~wudka/Physics7/Notes_www/node5.html

http://pc65.frontier.osrhe.edu/hs/science/pmethod.htm

http://www.visionlearning.com/myclassroom/courses/NSC107_Carpi_index.htm

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ACTIVITIES

Students will design a problem that can be tested by the scientific method. Students will explain each step of the scientific method as it pertains to the imaginary research problem and orally present their work to the class for peer critique.

Example: Using each step of the scientific method, describe what should be done to determine if a particular drug (DM2001) inhibits the reproduction of the deadly Bacteria S18. Identify all variables. Communicate the hypothesis and project design to the rest of the class for peer evaluation of the use of the scientific method, variable identification, and design. State how you

would determine whether the new drug would be a good choice for therapy and what impact its use may have on society.

MATERIALS NEEDED

Common Mistakes Made By Beginning Researchers Handout

ASSESSMENT

Scientific Method Rubric-Critique Form
Instructions for Scientific Method Rubric-Critique Form
Scientific Method Self-Evaluation Form

REFLECTIONS

Teacher note: Encourage students to combine their research project with science fair, physics projects, and/or technical writing assignments.

COMMON MISTAKES MADE BY BEGINNING RESEARCHERS

1. Puts off selection of a problem until all or most of course work has been finished.

2. Accepts the first research idea that is thought of or suggested.

3. Selects a problem that is too vast or too vague to investigate meaningfully. (poorly designed).

4. Prepares a hypothesis that is not testable.

5. Fails to consider methods or analytical procedures in developing a tentative research plan.

6. Carries out a hurried literature review in order to get started on the research project.

7. Fails to thoroughly evaluate the instruments available for data collection before selecting those to be used in the research. This often leads to the use of invalid or inappropriate methods.

8. Collects research data, then tries to find a statistical technique that can be used in the analysis.

9. Selects a statistical tool that is inappropriate for the proposed analysis.

10. Fails to define the research target population.

11. Attempts to carry out a study in a few months that would require 2-3 years to do satisfactorily.

12. Uses a sample that is too small to permit proper analysis of interesting subgroups.

13. Attempts to conduct research using volunteer subjects only.

14. Changes the experimental design in ways that weakens the research in order to make the data collection more convenient.

15. Asks too many questions, making unreasonable demands on the respondent's time.

Source: Handbook In Research and Evaluation by Stephen Isaac and William Michael

SCIENTIFIC METHOD CRITIQUE FORM

STUDENT'S NAME: _____Date: _____

	Criteria	Possible Points	**Points Received**
1	Accurately stated the problem	5	
2	Adequate background research	15	
3	Testable hypothesis	10	
4	Clearly described experiment design	20	
5	Described control group	10	
6	Adequately identified experimental group	10	
7	Data collection relevant to project	10	
8	Demonstrated repetition	10	
9	Stated conclusion based on data and relevant to hypothesis	10	
	TOTAL POINTS	**100**	

Most outstanding quality:

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Suggestions for improvement:

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Evaluator's signature: _____

EXPLANATION OF SCIENTIFIC METHOD RUBRIC

1	Accurately stated the problem	5
2	Adequate background research	15
3	Testable hypothesis	10
4	Clearly described experiment design	20
5	Described control group	10
6	Adequately identified experimental group	10
7	Data collection relevant to project	10
8	Demonstrated repetition	10
9	Stated conclusion based on data and relevant to hypothesis	10

1. STATE THE PROBLEM: The problem is usually stated as a question to be solved. It MUST be testable! (5 points maximum)

2. BACKGROUND RESEARCH / LITERATURE REVIEW: Evidence of background research must be presented. This may include library research of professional journals concerning the topic. (15 points maximum)

3. A TESTABLE HYPOTHESIS: The hypothesis MUST be testable. The student may state a null hypothesis, an alternative hypothesis, or both.
(10 points maximum)

4. DESCRIBE THE EXPERIMENT: The student must include all factors that may affect the results of the experiment, including independent variables, dependent variables, and control variables. (20 points maximum)

5. DESCRIBE THE CONTROL GROUP: A control variable – kept the same in both groups - must be included, identified, and described. (10 points maximum)

6. DESCRIBE THE EXPERIMENTAL GROUP: The student must identify the experimental group – the one composed of the independent variable.
(10 points maximum)

7. DESCRIBE RELEVANT COLLECTIBLE DATA: Student will describe data to be collected. Describe graph(s) or charts that would be appropriate.
(10 points maximum)

8. DEMONSTRATE REPETITION: The student must describe either multiple trials or multiple experimental setups. (10 points maximum)

9. STATE A CONCLUSION BASED ON THE DATA: The conclusion MUST be based on the collected data. The conclusion should either support or reject the *stated hypothesis*. Rejection of the hypothesis is perfectly acceptable. Researchers often must reject their hypotheses. (10 points maximum)

SCIENTIFIC METHOD SELF-EVALUATION FORM

STUDENT'S NAME: _____

Criteria	Possible Points	**Points Received**
Accurately stated the problem	10	
Adequate background research	10	
Testable hypothesis	10	
Clearly described experiment design	20	
Described control group	10	
Adequately identified experimental group	10	
Data collection relevant to project	10	
Demonstrated repetition	10	
Stated conclusion based on data and relevant to hypothesis	10	
Total Points	**100**	

Strongest quality:

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Areas for improvement:

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Plan of Action:

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