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AUTHOR Crawley, Frank E.; Arditzoglou, Sophia Yani
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ABSTRACT

Misconceptions are systematic, intelligently conceived, and quite reasonable theories that have been constructed on the basis of experience. Research studies on misconceptions have indicated that students develop intelligently conceived and sophisticated concepts of science. Although some of these are compatible with the principles of modern science, others are incorrect, outdated, or unacceptable in a science-oriented culture. The views of science held by elementary students and the extent to which their views can be modified will depend on the teachers' conceptions. Possessing misconceptions will most certainly cripple the teachers' ability to identify and correct the misunderstandings students bring with them into the classroom. This study aimed to identify the life and physical science misconceptions of preservice elementary teachers enrolled in three sections of a science methods course offered at the University of Texas at Austin during the spring semester of 1988. In particular, the study had as objectives, to: (1) identify preservice teachers' misconceptions in the physical and life science concepts; (2) develop, field test, and revise multiple-choice test items designed to identify the physical and life science misconceptions of preservice elementary teachers; and (3) correlate the scores on the pilot versions of the "Physical Science Misconceptions Test" and "Life Science Misconceptions Test" to preservice teachers' academic ability/achievement indices of science and math knowledge. (Author/CW)

Life and Physical Science Misconceptions of Preservice Elementary Teachers

Frank E. Crawley and Sophia Yani Arditzoglou
Science Education Center - EDB 340
University of Texas at Austin
Austin, Texas 78712

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Purpose

Science educators need to be concerned with the long-term effects of misunderstandings of elementary preservice teachers. The views of science held by elementary students and the extent to which their views can be modified will depend on the teachers' conceptions. Possessing misconceptions will most certainly cripple the teachers' ability to identify and correct the misunderstandings students bring with them into the classroom. Ultimately, the development of scientifically literate citizens that are capable of making responsible decisions concerning the environment and the society in which we live will be difficult to attain. Since it is this interaction of children's science and their teachers' science that will have profound implications on the outcomes of teaching, it was deemed important to explore teachers' science conceptions and provide some answers to the question "What misconceptions, if any, do preservice elementary teachers possess with respect to science concepts they are expected to understand to be able to teach to their elementary students in the future?"

The study aimed to identify Life and Physical Science misconceptions of preservice elementary teachers enrolled in three sections of a science methods course offered at the University of Texas at Austin during the Spring semester of 1988.

In particular, the study had the following objectives:

1. Identify preservice teachers' misconceptions in the physical and life science concepts that
    a. substantially disagree with the scientifically-accepted definitions,
    b. greatly resemble science misconceptions as identified by previous studies.
2. Develop, field test, and revise multiple-choice test items designed to identify the physical and life science misconceptions of preservice elementary teachers.
3. Correlate the scores on the pilot versions of the "Physical Science Misconceptions Test" and "Life Science Misconceptions Test" to preservice teachers' academic ability/achievement indices of science and math knowledge.

Rationale

Misconceptions are systematic, intelligently conceived, and quite reasonable theories that have been constructed on the basis of experience (Clement, 1982). Over the past two decades, research studies on misconceptions indicated that students develop intelligently conceived and sophisticated concepts of science. Although some of these are compatible with the principles of modern science; others are incorrect, outdated, or unacceptable in a science-oriented culture (Ault, 1984; Clement, 1982; Driver, 1983; Kuethe, 1963). These views of the world and meanings for words are not simply isolated ideas but rather they are part of conceptual structures which provide a personal, sensible and coherent understanding of the world (Champagne, Klopfer, & Anderson, 1980). Such beliefs and expectations usually are held very strongly (Clement, 1977; Nussbaum & Novak, 1976; Leboutet-Barrell, 1976; Stead & Osborne, 1980); and consequently, naive theories are highly resistant to change or alteration (Caramazza, McCloskey, & Green, 1981; Champagne, Klopfer, & Anderson, 1980; Clement, 1982; Driver, 1983).

In the study of learning, the problem of science misconceptions surfaces in virtually every science-related field (Pfundt &Duit, 1985; and Za'rour, 1976) and spans the full spectrum of education (Ault, 1984; di Sessa, 1982; Driver, 1983; Eaten, Anderson, & Smith, 1983; Kuethe, 1963; McCloskey,1983; Viennot, 1979). During lesson preparation, teachers' views of science interact with science curriculum and its materials ultimately producing a resultant viewpoint presented by teachers to pupils. Ideally, the teacher's role is to help students develop a meaningful understanding of scientific concepts, one that is appreciated and used to relate to the environment in which they live (Klausmeier, Ghatala, & Frayer, 1974). The usability of a concept implies that students will be able to (a) generalize to new instances or discriminate non-instances of the concept; (b) recognize other concepts in a taxonomy as supra-ordinate, co-ordinate or sub-ordinate; (c) recognize cause-effect, correlational, probability and axiomatic relationships among concepts; and (d) solve problems involving the concept (Okebukola & Jegede, 1988).

Therefore teachers must understand the concepts they are expected to teach in such a way that their views of science closely relate to scientists' science. Although teacher content knowledge may not be perceived as the critical determinant of effective teaching by teachers, supervisors, principals, or administrators (O'Neil, 1986); and selected science educators (Tulloch, 1986; Hollis-Melton, 1986), it has attracted significant attention among researchers. Lawrenz (1986) uncovered serious misconceptions in selected physical science topics among 333 Arizona elementary teachers, and Ameh & Gunstone (1985) observed deficiencies among secondary science teacher trainees in Australia. In a study of preservice elementary science students, Stepans & McCormack (1985) observed that additional work in traditional science courses and better understanding of basic science concepts were not correlated among the sample studied.

Design and Procedures

Subjects participating in this study consisted of 49 preservice elementary teachers enrolled in three sections of a science methods course offered at the University of Texas at Austin, during the Spring Semester, 1988. On the average, participants were 24.8 years of age (S.D. = 6.50, with a range of 20 - 45), had a high school GPA of 3.48 on a scale of 4.0 = A (S.D. = .45, with a range of 2.5 - 4.6), and reported an undergraduate GPA of 3.09 on a scale of 4.0 = A (S.D. = .49, with a range of 2.3 - 4.0). The number of high school courses completed by the subjects ranged from 0 to 4 in life sciences, 1 to 6 in physical sciences, and 2 to 12 in mathematics. The number of college life science, physical science, and mathematics courses completed ranged from 0 to 6, 0 to 3, and 0 to 7, respectively. Participants' average SAT (verbal) score was 433.75 (S.D. = 62, with a range of 380 - 530), and the average SAT (quantitative) score was 450 (S.D. = 67.23, with a range of 380 - 610). Of the 49 teachers completing the "Physical Science Misconceptions Test (Pilot version)", 29 were seniors, 7 were juniors, 12 were graduates who had returned for certification, and 1 was a special student. Although teachers' self-reported understanding of physical science concepts ranged from poor to above average, the mean rating for physical science concepts was reported to be "average".

A large pool of life and physical science misconceptions initially was formulated from a review of previous research on the topic. Three fifth- and sixth-grade science textbooks (viz., Gateways to Science: Grades 5 and 6; Heath Science: Grades 5 and 6; Modern Elementary Science: Grades 5 and 6) commonly in use in Texas' schools were examined. From the pool of misconception items identified in the literature, only life and physical science concepts that teachers were expected to understand to be able to teach science in the elementary grades were retained. Open-ended questions were written for each of the seven physical science concepts: motion, electricity, floating/ sinking, states of matter, heat and temperature, air pressure, and light. In the case of the life science, open-ended questions were written for each the following concepts: life, cells, plants, animals and animal classification, evolution and natural selection, prey-predator relationships, four systems of the human body (circulatory, digestive, respiratory, and nervous systems), and nutrition-photosynthesis-respiration. Groups of five to six participants in each science methods class were randomly selected to provide responses to the open-ended concept tests, consisting of 8-10 questions. With each test, subjects' responses remained confidential.

Responses to the questionnaires were content analyzed to identify four to five free-standing options for each subsequent multiple-choice item. Alternatives included the naive/incomplete explanations of life and physical science concepts, and in some cases the correct, scientific explanation whenever it was supplied by survey participants. Alternatives were then transformed into plausible distractors for use as options on the "Life and Physical Science Misconceptions Tests (Pilot versions)".

Prior to administering the pilot test, each item was reviewed by two faculty members (a science educator and an educational psychologist) to identify faulty wording and item construction errors. Items that were viewed as being too complicated, difficult, or improperly phrased were revised and distractors for each item were constructed to have approximately the same length and to be free of clues. The pilot version of the "Physical Science Misconceptions Test" contained 41 multiple-choice items, each of which incorporated five plausible alternatives. The pilot version of the "Life Science Misconceptions Test" contained 40 multiple-choice items, each of which also incorporated five plausible alternatives. The option "none of the above", was the correct response for each item to which the correct response was not provided by participants on the open-ended survey questionnaire. Since four of the five alternatives represented misconceptions, the maximum number of misconceptions incorporated in the 41-item Physical Science Misconceptions Test was 164, whereas the 40-item Life Science Misconceptions Test incorporated 160 misconceptions.

Of the fifty-nine preservice teachers who completed the open-ended questionnaires, 49 completed the pilot versions of the "Misconceptions Tests". Specific information on past education and grades was gathered to examine the association between specific education-related variables and the number of misconceptions. Variables of interest in this study included: age, high school GPA, verbal and quantitative scores on the SAT, undergraduate GPA, university status, number of life science/physical science/mathematics courses taken at the high school and college levels, and self-reported ratings of participants' understanding of physical science concepts.

Life Science Misconceptions

Data obtained from the "Life Science Misconceptions Test" were analyzed using the item analysis procedures developed by Herbert (1948). Tests were scored; the popularity of each alternative was calculated; and popular distractors were identified, i.e., options selected by more than the number of people expected by chance ($p > 0.20$ for a 5-option item). These options were labelled "Misconceptions" (see Table 1). Subgroups were subsequently formed by collecting misconceptions related to the same general concept, and the mean percentage popularity of misconceptions was computed for each subgroup. The level of significance adopted for the correlational study was .10 ($p \leq .10$).

Table 1

Number of Misconceptions per Topic

Topic	Items(#)	Options (#)	Option Selection Frequency		
			$p = 0$	$0 < p \leq .20$	$p > .20$
Living/Nonliving	6	30	0	21	9
Cells	2	10	0	7	3
Plants	4	20	1	11	8
Animals and Animal Classification	8	40	5	17	18
Evolution and Natural Selection	2	10	1	6	3
Prey-Predator Relationships	4	20	3	12	5
Human Circulation	4	20	3	11	6
Human Digestion	4	20	6	8	6
Human Respiration	4	20	3	9	8
Human Nervous System	2	10	1	4	5
Total	40	200	23	106	71

Note. $p > .20$ operationally defines a misconception except for correct options.

The average number of correct responses scored by the 49 individuals on the pilot version of the 40-item "Life Science Misconceptions Test" was 13.9 (S.D. = 3.5, with a range of 7 - 22). Low scores on the test indicated that this particular group of preservice elementary teachers was unaware of the correct scientific explanations to some of the concepts included on the test. Consequently, an investigation of specific misconceptions addressed in each item included on the test was pursued.

Preservice teachers believed inanimate objects to be nonliving because they are neither plants nor animals (39%); do not possess reproductive, sensory, and respiratory systems (43%); and can exist without a food source (41%). In plants, life was characterized by the ability to develop from a seed and to produce its own food source (44%). When asked about the type of evidence one should look for to determine whether life ever existed on a planet, teachers most frequently (39%) selected the distractor "water, oxygen, and an energy source". When the concept of cells was tested, 27% of the subjects believed that cells differ structurally due to functional differences. The criterion teachers utilized to justify the discrimination between cells is the presence of chloroplasts in plant cells but not in animal cells (see Table 2).

Table 2

Misconceptions Related to "Living / Nonliving and Cells"

Topic/Item	Popularity (%)
Living / Nonliving	
1. A tree is a living organism because it is a plant that develops from a seed and makes its own food.	44
2. A river is not alive because it is neither a plant nor an animal.	39
3. Unlike inanimate objects, plants and animals possess reproductive, sensory, and respiratory systems.	43
4. Both plants and animals cannot survive without food source but inanimate objects can do without it.	41
5. Water, oxygen and a source of energy are used to determine whether living organisms ever existed on a planet.	39
Cells	
1. Chloroplasts found in plant cells but not in animal cells, result in structural differences between these cells since they are functionally dissimilar.	27

More than half (59%) of the subjects believed that seeds found in a moist but dark environment will die since they lack the sunlight needed to produce food. About 30% of the teachers preferred the superficial definition of photosynthesis to the more specific scientific one. Finally, 23% of the participants thought that plant food - usually bought from the store - facilitates the absorption of carbon dioxide from the atmosphere and consequently helps the plant to grow. Thirty percent (30%) of the participants identified an animal as being any type of multicellular living thing that is not classified as a plant. On the other hand, four misconceptions related to animal classification were identified. An eel was considered to be either a vertebrate fish (27%), an invertebrate fish (33%), or an invertebrate amphibian (22%). A jellyfish was thought to be an invertebrate sponge (27%); whereas a turtle was seen as a vertebrate amphibian (29%) or an invertebrate reptile (25%). A starfish was thought to be a vertebrate fish (25%) or an invertebrate fish (22%) (see Table 3).

Table 3

Misconceptions Related to "Plants and Animals / Animal Classification"

Topic/Item	Popularity (%)
Plants	
1. Seeds that fall into a dark but moist environment die because they need sunlight to produce their own food.	59
2. Plant food bought from the store facilitates the absorption of carbon dioxide and consequently helps the plant grow.	23
3. Photosynthesis is the process by which plants get their energy source from the sun.	31
Animals	
1. Animals are any type of multicellular living things that are not classified as plants.	31
Animal Classification	
1. An eel is a (an)	
a. invertebrate fish.	33
b. invertebrate amphibian.	22
2. A jellyfish is an invertebrate sponge.	27
3. A turtle is a (an)	
a. vertebrate amphibian.	29
b. invertebrate reptile.	25
4. A starfish is a (an)	
a. vertebrate fish.	25
b. invertebrate fish.	22

One of the three misconceptions related to the topic of evolution and natural selection was quite popular. About 60% of the preservice teachers believed that new traits in some animals develop due to need, while in other animals new traits are produced by chance mutation. In addition, 43% of the subjects indicated that the fittest animal is the one that survives for the longest period of time, and another 43% attributed the quality of adaptability to a new environment as characterizing the fittest animal.

Prey-predator misconceptions were evident. All life was thought to depend on green plants because they provide all other organisms with a constant supply of oxygen (59%), or because plants are important links in the complex web of interaction among living things (37%). Furthermore, 55% of the teachers believed that "a population located higher on a food chain is a predator of more than one population at different levels below it" (see Table 4).

Table 4

Misconceptions Related to "Evolution / Natural Selection and Prey-Predator Relationships"

Topic/Item	Popularity (%)
Evolution / Natural Selection	
1. In some animals a new trait develops due to need while in others it results from chance mutation.	61
2. The fittest animal is the one that	
a. survives the longest period of time.	43
b. is capable of adapting to a totally new environment.	43
Prey-Predator Relationships	
1. All of life depends on green plants because they	
a. provide all other organisms with a constant supply of oxygen.	59
b. are important links in the complex web of interactions among living things.	37
2. A population located higher on a food chain is a predator of more than one population at different levels below it.	55

Three misconceptions were identified within the topic of the human circulatory system (see Table 5). More than 80% of the respondents believed that the blood's primary function is to carry oxygen and nutrients to every cell in all parts of the body, and they did not consider the importance of blood in regulating temperature or removing metabolic waste products. Although more than 45% of the subjects knew that nutrients, gases, and waste products are exchanged when blood reaches the cells; they failed to recognize that this process occurs through capillaries. To describe the blood, almost 40% of the preservice teachers considered it to be a red liquid that clots easily when exposed to air; while 33% thought that it consists of red and white blood cells.

About half the preservice teachers held misconceptions regarding the human digestive system, in particular the pathway food travels through the body as it leaves the mouth (see Table 5). Teachers believed food passes through the large intestine before entering the small intestine, suggesting that they were familiar with only the first parts of the digestive tract. When asked to explain what happens to ingested foods, 27% of the teachers thought that "most of the food is stored in the numerous fat cells found under the skin".

Almost 90% of the subjects believed that the process of breathing is used to supply cells with oxygen rather than fill the chest cavity with air (see Table 5). When asked to select the list containing the body parts involved in breathing, 27% of the preservice teachers chose "heart, lungs, and every cell in the body". Two misconceptions related to respiration were highlighted.

About half (45%) of the respondents thought that respiration refers to the process of inhaling oxygen and exhaling carbon dioxide, thus failing to distinguish between the processes of breathing and respiration. In addition, 37% of the preservice teachers considered respiration to occur at the cellular level but failed to recognize its primary goal to be the production of energy.

Misconceptions were identified related to the structure and function of the nervous system. About 30% of the teachers thought that the brain is a tissue comprised of specialized cells, while 25% referred to the brain as a complex system made of neurons. When asked about its function, more than 45% of the subjects believed that the brain integrates all incoming stimuli, and 35% believed that the brain is used for coordinating the psychological and physiological processes of the body (see Table 5).

Table 5

Misconceptions Related to "Human Body Systems"

Topic / Item	Popularity (%)
Human Circulatory System	
1. Blood is a red liquid that clots easily when exposed to air.	40
2. The blood's main function is to carry oxygen and nutrients to every cell in all parts of the body.	84
3. As blood reaches the cells nutrients, oxygen, waste products, and carbon dioxide are exchanged through arteries.	47
Human Digestive System	
1. As it leaves the mouth, food travels through the esophagus, stomach, large intestine, and finally the small intestine.	51
2. Most of the food humans eat is stored in the numerous fat cells found under the skin.	27
Human Respiratory System	
1. Through the process of breathing, we supply cells with oxygen.	90
2. Respiration is the process of	
a. inhaling oxygen and exhaling carbon dioxide.	45
b. exchanging gases at the cellular level.	37
Human Nervous System	
1. The function of the brain is to act as a	
a. central processing unit that integrates all incoming stimuli.	47
b. control of the physiological and psychological processes of the body.	
2. Structurally, the brain consists of a	
a. tissue comprised of specialized nerve cells.	29
b. complex system consisting of many neurons.	25

Misconception subgroups in the life sciences were formed by grouping items related to the same life science concept, then computing the mean percentage popularity of misconceptions within each subgroup. Summarizing the results in this way, it was noticed that the mean percentage popularities range from 27% to 57%. The lowest mean percentage popularities (27%) were found in the misconception subgroups labelled "cells" and "animals". By contrast, teachers endorsed the greatest percentage of misconceptions in the subgroups "human circulatory system" (57%), "human respiratory system" (57%), "evolution and natural selection" (49%), and "prey-predator relationships" (57%). Misconceptions related to the topics of "living and nonliving", "human digestive system", and "plants" ranged in popularity from 38% to 41% (see Table 6).

Table 6

Mean Percentage Popularities of Life Science Misconception Subgroups

Topic	Number of Items per Topic	Number of Misconceptions per Topic	Mean Popularity (%) of Misconceptions within Subgroup
Life/death	6	5	41
Cell	2	1	27
Plants	4	3	38
Animals	8	9	27
Evolution and Natural Selection	2	3	49
Prey-Predator Relationships	4	3	57
Body Systems			
Circulation	4	3	57
Digestion	4	2	39
Respiration	4	3	57
Nervous	2	4	34
Total	40	36	43

Results of this study indicate that preservice teachers enrolled in three sections of an elementary science methods course, possess life science concepts whose meanings conflict with that of scientists. These findings should draw attention to the fact that preservice elementary teachers develop naive theories regarding specific life science concepts that they should understand if they are to teach these concepts to elementary grade students. In particular, preservice elementary teachers participating in the study possess a total of 36 life science misconceptions, that are distributed in the following manner: 4 of 8 possible in human nervous system, 3 of 8 possible in evolution and natural selection, 9 of 32 possible in animal and animal classification, 5 of 24 possible in living and nonliving, 3 of 16 possible in plants, 3 of 16 possible in prey-predator relationships, 3 of 16 possible in human respiration, 3 of 16 possible in human circulation, 2 of 16 possible in human digestion, and 1 of 8 possible in cells.

The relationship between preservice teachers' past education in science and their misconceptions was explored in a follow-up correlational study. For exploratory purposes, a probability level of $p \leq .10$ was adopted as significant for correlation coefficients. Although correlation coefficients (r) computed between the classificatory information and the test scores appeared to be relatively high, only five of the fourteen variables reached significance ($p \leq .10$). The variables found to be associated with test performance were verbal SAT scores ($r=.56$, $p=.0762$), age ($r=.28$, $p=.0541$), university GPA ($r=.55$, $p=.0001$), number of high school mathematics courses completed ($r=.29$, $p=.0435$), and self-reported ratings of preservice teachers' understanding of life science concepts ($r=.30$, $p=.0401$). On the other hand, nonsignificant correlations were found to exist between life science misconceptions test scores and high school GPA; number of high school physical science and life science courses completed; number of college math, life science and physical science courses completed; university classification; and self-reported ratings of physical science understanding (see Table 7).

Table 7

Correlation Between Life Science Misconceptions Test Scores and Variables

Variable	r	p
Age	.28	.0514
SAT Score		
Verbal	.56	.0762
Quantitative	.48	.1397
GPA		
High School	.01	.9766
High School Courses		
Life Sciences	.01	.9361
Physics	.04	.7911
Math	.29	.0435
College Courses		
Life Sciences	.17	.2684
Physics	.20	.1781
Math	.23	.1128
University Classification	.19	.1927
Rated understanding of		
Life Sciences	.30	.0401
Physics	.09	.5407

Physical Science Misconceptions

Data obtained from the "Physical Science Misconceptions Test" were analyzed using the item analysis procedures developed by Herbert (1948). Tests were scored; the popularity of each alternative was calculated; and popular distractors were identified, i.e., options selected by more than the number of people expected by chance (p > 0.20 for a 5-option item). These options were labelled "Misconceptions" (see Table 8). Subgroups were subsequently formed by collecting misconceptions related to the same general concept, and the mean percentage popularity of misconceptions was computed for each subgroup. The level of significance adopted for the correlational study was .10 (p ≤.10).

Table 8

Number of Options per Topic

Topic	Items(#)	Options (#)	Option Selection Frequency		
			p=0	0<p≤.20	p>.20
Motion	9	45	5	24	16
Electricity	6	30	1	15	1
Floating and Sinking	8	40	3	24	13
States of Matter	6	30	2	19	9
Heat and Temperature	4	20	0	13	7
Air Pressure	4	20	0	13	7
Light	4	20	0	13	7
Total	41	205	11	121	73

Note. p > .20 operationally defines a misconception except for correct options.

The average number of scientifically correct responses scored by the 49 individuals on the 41-item "Physical Science Misconceptions (Pilot Test)" was 13.1 (S.D. = 3.6), with a range of 7 - 21. Low scores on the test indicated that this particular group of preservice elementary teachers was unaware of the correct scientific explanations to many of the physical science concepts included on the test. Consequently, an investigation of specific misconceptions addressed in each item included on the test was pursued.

Within the concept of motion, five of the twelve misconceptions identified had a percentage popularity of more than 50%. Preservice teachers believed that a heavy ball dropped from the top of the mast of a sailing ship strikes the deck behind the mast (61%); a bolt released from the ceiling of a moving boxcar - directly above a hole - hits the boxcar behind the hole (53%); when identical balls are rolled off the edge of a table, the ball that hits the ground first is either the fastest one (51%) or the slowest one (25%); a ball released by a moving conveyor belt falls straight down to the ground (53%); and a man walking who drops a ball from his side finds the ball lands in front (47%) or behind (22%) him as it hits the ground. The subjects indicated that a ball shot through a circular tube moves in a straight line for some distance before following a curved path typical of projectile motion (43%); when compared to a bullet fired from a horizontal muzzle, a ball falling straight down reaches the ground before (35%) or after (27%) the bullet; a ball thrown upward at an initial angle of 45 degrees either falls straight down after reaching a maximum height

(22%), or follows a path at right angles to the direction in which the ball was originally thrown (22%)(see Table 9).

Table 9

Misconceptions Related to "Motion"

Item	Popularity (%)
1. A heavy ball dropped from the top of the mast of a ship- sailing rapidly - strikes the deck behind the mast.	61
2. A ball that is attached to an electromagnet moving at a constant speed, falls straight down to the ground when released.	53
3. A ball released by a person walking on a level surface at a constant speed will fall to the ground travelling in a straight line.	53
4. When the ball - released by the walking man - hits the ground, the man is	
a. in front of the ball.	47
b. behind the ball.	22
5. When identical balls are rolled off the edge of a table, the one that hits the ground first is the: a. faster one.	51
b. slower one.	25
6. A bolt released from a bolt on the ceiling of a moving boxcar - with a hole directly below the bolt - will hit the ground behind the hole.	53
7. A ball shot through a circular tube with a 90 degree segment removed, travels in a straight line for some time before following a curved path.	43
8. A bullet is fired horizontally from a gun placed at exactly the same as a ball that is released at the same time. The ball is found to hit the ground	
a. before the bullet	35
b. after the bullet	27
9. A ball thrown upward at an initial angle of 45 degrees reaches a maximum height and then falls straight down.	22

Twenty eight percent of the subjects believed that the brightness of a bulb increases when a resistor placed between it and the positive end of the battery is changed; however, a change in resistance near the battery's negative end has no effect on the brightness of the bulb (27%)(see Table 10).

Table 10

Misconceptions Related to "Electricity"

Item	Popularity (%)
1. Changing the resistor closer to the positive end of the battery increases the brightness of the bulb in a circuit.	28
2. Changing the resistor closer to the negative end of the battery does not increase the brightness of the bulb in a circuit.	27

Note. Diagrams were included on electric circuit items.

The concept of floating and sinking revealed five types of misconceptions existing among preservice elementary teachers (see Table 11). An object's buoyancy was thought to determine whether it floats or sinks (33%); and a floating object was thought to displace more salt water than fresh water because salt water is heavier than fresh water (33%). When asked to compare the water levels on an object placed in fresh and salt water, teachers reported the levels to be either the same in both fresh and salt water (22%), higher in fresh water because it is heavier (31%) or lighter (33%) than salt water. Also, a beer bottle almost full with water was reported to sink because the bottle and the water together are less dense than the water in which they are floating (27%).

Percentage popularities of misconceptions within "states of matter" ranged from 26% to 67% (see Table 12). Preservice teachers thought that solid objects retain their shape because molecules in solids are packed more closely than are molecules in liquids (65%); large bubbles in boiling water are made of oxygen released from the water molecules (57%), or air trapped in the water (29%); and molecules in frozen water are packed more tightly than those in liquid water (53%). In the lake reversal problem, the insulating effect of the earth (43%) and the sun's ability to heat water at the top of the lake in the summer (31%) were used to explain why water at the bottom of the lake remained about the same temperature; whereas the earth's insulation (41%) and earth's heat (26%) were used to explain the observation that the "water temperature at the bottom of the lake never gets below 39 degrees Fahrenheit".

Teachers revealed misconceptions related to the topics of heat and temperature. When compared to a thin rod, teachers thought a larger diameter rod of greater mass transmits more heat (31%) or retain more heat (31%); a pot of water boiling for several minutes reaches a temperature of a few degrees higher than 100 degrees Celsius (22%); and temperature is defined as a measure of the total heat contained in an object (47%) (see Table 13).

Preservice elementary teachers believed that a light beam striking the surface of a mirror is reflected at an angle either greater than the angle of incidence (37%) or perpendicular to the surface of the mirror (33%); but when the same light beam strikes frosted glass, light rays are reflected in only one direction and either at an angle greater than the angle of incidence (37%) or equal to the angle of incidence (33%) (see Table 14).

Table 11
Misconceptions Related to "Floating and Sinking"

Item	Popularity (%)
1. Some things float and others do not because some things have buoyancy and others do not.	33
2. An object displaces more salt water than fresh water because salt water is heavier than fresh water.	33
3. When compared to salty water, the level of fresh water on a boat's surface is	
a. the same because the boat displaces the same amount of water	22
b. higher because fresh water is heavier that salty water	31
c. higher because salt water is heavier than fresh water	33
4. A beer bottle almost full with water sinks because the bottle and the water together are less dense than water in the lake.	27

Table 12
Misconceptions Related to "States of Matter"

Item	Popularity (%)
1. Solid objects retain their shape because molecules in solids are packed more closely than are molecules in liquids.	65
2. Large bubbles seen in boiling water come from	
a. oxygen released from the water molecules.	57
b. trapped air in the water.	29
3. Molecules in frozen water are packed more tightly than those in liquid water.	53
4. Only by adding salt to ice cubes one can make sure that the cubes melt quickly.	47
5. During summer, water at the bottom of a lake remains about the same temperature as that during the winter due to the	
a. insulating effect of the earth.	43
b. sun heating the water at the top of the lake.	31
6. The temperature of water at the bottom of the lake never gets below 39 degrees Fahrenheit due to the earth's a. insulation.	41
b. heat.	26

Table 13

Misconceptions Related to "Heat and Temperature"

Item	Popularity (%)
1. Temperature is a measure of the total heat contained in an object.	47
2. The greater mass of a rod with a large diameter enables it to	
a. transmit more heat.	31
b. retain more heat.	31
3. The temperature of a pot of water boiling for several minutes is a few degrees higher than 100 degrees Celsius.	22

Table 14

Misconceptions Related to "Light"

Item	Popularity (%)
1. A light beam striking the surface of a mirror is reflected at an angle	
a. greater than the angle of incidence.	37
b. perpendicular to the surface of the mirror.	33
2. A light beam striking frosted glass is reflected in only one direction and at an angle	
a. greater than the angle of incidence.	37
b. equal to the angle of incidence.	33

Within the concept of "air pressure", the precept "for every action there is an equal and opposite reaction" was used by teachers to explain the opposing movements of pistons joined together by a flexible tube (43%). Suction inside a previously sealed but inverted cup was thought to prevent its contents from falling (43%), but making a hole in this inverted cup causes the contents to fall out due to either the release of trapped air (33%) or the absence of air pressure needed to hold the contents in place (37%). Removing air from a container, according to teachers, causes its walls to collapse either because a temperature difference between air outside and inside the container exerts pressure on the walls (37%), or because air inside the container condenses and contracts (27%) (see Table 15).

Table 15
Misconceptions Related to "Air Pressure"

Item	Popularity (%)
1. Opposing movements of pistons whose syringes are joined by a flexible tube is based on the precept "For every action there is an equal and opposite reaction".	43
2. Suction inside a previously sealed plastic cup whose seal has been removed prevents the cup's contents from falling out.	43
3. Making a hole in the inverted cup causes its contents to fall out due to	
a. releasing the air trapped in it.	33
b. the absence of air pressure that is needed to hold the contents in.	37
4. Removing air from a container - by boiling a little water in it, capping it and allowing it to cool - causes the walls to collapse because	
a. temperature difference between air outside and inside the container exerts pressure on the walls.	37
b. air inside the container condenses and contracts.	27

Physical science misconceptions related to the same concept were grouped together, and the mean percentage popularity of misconceptions within each subgroup was calculated. By employing this method, mean percentage popularities for the physical science misconception subgroups were found to range from 27% to 44%. "States of Matter" was the topic that contained the largest mean percentage of misconceptions(44%), followed by "Motion" (41%). The misconception subgroup with the lowest percentage popularity was "Electricity"(27%). Five misconception subgroups had mean percentage popularities ranging between 30% and 37%. Within this set, the lowest one was related to "Floating and Sinking"(30%); and the largest one was found for the topic of "Air Pressure"(37%, see Table 16).

Table 16

Mean Percentage Popularities of Physical Science Misconception Subgroups

Subgroup Topic	Number of Items per Topic	Number of Misconceptions per Topic	Mean Popularity (%) of Misconceptions within Subgroup
Motion	9	12	41
Electricity	6	8	27
Floating and Sinking	8	6	30
States of Matter	6	9	44
Heat / Temperature	4	4	33
Air Pressure	4	6	37
Light	4	4	35
Total	41	50	36

For exploratory purposes, a probability level of $p \leq .10$ was adopted as significant in a follow-up correlational study that examined the relationship between past education and misconceptions. Of the fourteen classificatory variables that were examined, only three correlated significantly ($p \leq .10$) with test scores. Variables found to be associated with test performance were age ($r=.32$, $p=.040$), university GPA ($r=.29$, $p=.0773$), and number of college physics courses completed ($r=.32$, $p=.0526$). On the other hand, nonsignificant correlations were found to exist between test scores and verbal or quantitative SAT scores; high school GPA; number of high school mathematics, physical science and life science courses completed; number of college math and life science courses completed; university classification; and the self-reported ratings of physical science and life science understanding (see Table 17).

In general, preservice teachers possess a total of 50 physical science misconceptions that are distributed in the following manner: 9 of 24 possible in "states of matter", 6 of 16 possible in "air pressure", 12 of 36 possible in "motion", 8 of 24 possible in "electricity ", 4 of 16 possible in "heat and temperature", 4 of 16 possible in "light", and 6 of 32 possible in "floating and sinking".

Table 17

Correlation Between Physical Science Misconceptions Test Scores and Variables

Variable	r	p
Age	.32	.0480
SAT Score		
Verbal	.45	.1970
Quantitative	.27	.4597
GPA		
High School	.04	.8407
University	.29	.0773
High School Courses		
Life Sciences	-.15	.3820
Physics	.07	.6841
Math	-.01	.9527
College Courses		
Life Sciences	-.21	.2183
Physics	.32	.0526
Math	.08	.6201
University Classification	.06	.7058
Rated understanding of		
Life Sciences	.13	.4521
Physics	.10	.5551

When comparing the number of life and physical science misconceptions, older subjects with higher university GPAs had fewer misconceptions in both life and physical sciences. However, university GPA was found to have a stronger positive correlation with the possession of scientifically acceptable life science concepts; while age tended to have a slightly better positive correlation with the number of physical science misconceptions the subjects possessed.

Discussion and Implications

The results of the study indicated that in many science methods courses, preservice elementary teachers possess science concepts whose meanings conflict with that of scientists. For example, misconceptions related to the concepts of motion and evolution were found to replicate the theories that were once held to be correct by scientists. The misconception "need leads to the development of new traits" was found to be similar to the Lamarckian theory of evolution. As for motion, the "straight-down belief" seemed to dominate the teachers conceptions of projectile. In this case, the object was thought to follow along the original direction of the path it was thrown, reach a maximum height, and then fall straight down. This belief replicated the "impetus theory" discussed by Philoponus in the sixth century and developed in detail by Burdian in the fourteenth century. As suggested by Prather (1985) and Wandersee

(1986), a systematic inclusion of the history of development of the major conceptual areas might help preservice teachers to recognize the inadequacies of their own incorrect ideas and gain an appreciation for the nature and value of science. To learn that some of their misconceptions were once held to be correct by outstanding scientists should help preservice elementary teachers maintain their intellectual self-confidence as they are introduced to more recent scientific findings. Preservice teachers should be given the opportunity to review the history of the development of major life and physical science concepts in order to discover the strengths, weaknesses, and tentativeness of these concepts. They should also critique the competing concepts of scientists and learn for themselves the value of alternate concepts.

Another group of life science misconceptions was associated with meaningful understanding (viz. knowledge that is understood, appreciated, and used to relate to the environment in which one lives and works) of specific scientific terms such as respiration, breathing, photosynthesis, and systems/tissues. This group of misconceptions suggests that although preservice teachers show familiarity with biological terminology, they tend to have only a superficial understanding of the underlying processes and concepts incorporated within the terms. For example, although respiration is recognized to occur at the cellular level, teachers associate it with the exchange of gases rather than the production of energy. According to schema theory (Rumelhart, & Ortony, 1977; Greene, 1980), meaningful learning has not been achieved by this particular group of preservice teachers, since new knowledge has not been appropriately linked to prior knowledge to produce concepts that are consistent with scientific concepts and also incompatible with prior knowledge. Consequently, teachers do not realize that some of their concepts - which they assume to be scientifically acceptable - are actually faulty or incomplete. Knowing "what,"not "how" leads to rote learning in which students recite their knowledge but do not use it. Brumby (1984) concluded that lectures are insufficient in themselves to create sufficient conflict in students' minds to alter their existing understanding of science concepts. It is necessary to spend time in problem solving, in the application of concepts to real-world situations in order to bring about conceptual change in students.

Exercises requiring preservice teachers to construct diagrammatic or pictorial summaries - that paraphrase what they already know about a concept - are encouraged. Science educators can help preservice elementary teachers learn how to learn or learn how knowledge is constructed by using either one of two heuristic devices (viz, concept maps and Vee diagrams) developed by Novak and Gowin (1984). These approaches have been used with considerable success by students at virtually every grade level for almost a decade. When used with preservice elementary teachers, a concept map will help them discover and ascertain what they know or do not know about concepts in a discipline; differentiate and integrate similar and related concepts; and form important conceptual links between concepts (Cullen, 1983).

It should not be assumed that erroneous concepts will disappear and be replaced by correct information in the routine course of science instruction (di Sessa, 1982). Time should be invested to develop techniques for exploring the science misconceptions of preservice teachers, learning more about them, making preservice teachers more aware of their misconceptions, and developing strategies that will ultimately bring naive concepts into line with scientific perspectives. Teacher training centers ought to encourage preservice elementary teachers describe basic scientific concepts and processes in simple terms before proceeding with instruction. Whenever any discrepancies are discovered , instructors could help beginning teachers to identify their misconceptions, understand correct concepts, and resolve differences in their understanding before teaching life and physical science concepts to children.

Preservice teachers ought to be given the opportunity to suggest and defend alternative explanations and discuss or debate the relative merits and limitations of each. Subsequently, confrontational strategies (Nussbaum & Novick, 1982) must be used - by introducing discrepant and anomalous events - to force preservice teachers to wrestle with inconsistencies in their thinking. As a result, dissatisfaction with existing misconceptions is generated and when the new scientifically-acceptable concept is introduced, it is found to be intelligible, fruitful, and more plausible (Posner, Stride, Hewson, & Gertzog, 1982).

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