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The specific alternative conceptions associated with persons of low self-efficacy were:

That planets can be seen only with a telescope.
That dinosaurs lived at the same time as cave-men.
That rusty iron weighs less than the iron that it came from.
That electricity is used up in appliances.
That North is towards the top of a map of Antarctica.

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Self-Efficacy of Preservice Elementary Teachers and Alternative Conceptions of Science

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Completed June 10, 1997

ABSTRACT

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INTRODUCTION

Over the past two decades, numerous studies of inservice and preservice elementary teachers have shown that many of these teachers have a negative attitude toward science (Shrigley, 1974; Morrisey, 1981; Westerback, 1982; Feistritzer & Boyer, 1983; Pedersen & McCurdy, 1992). Of great concern is that teachers who have a negative attitude toward science can, through their own actions, pass this attitude on to the students in their classes (Stollberg, 1969, Scharmann & Orth Hampton, 1995).

In work developing his social learning theory, Bandura (1981, 1982) showed that people's beliefs in their own abilities had an effect on their performance. He found that behaviors occur when, (a) people believe in their own ability to perform that behavior and (b) people expect, based upon their own life experiences, that this behavior will result in a desirable outcome. This first belief, that people believe in their own ability, Bandura called self-efficacy. The second belief, that certain behaviors will result in a specific outcome is called outcome expectancy. Bandura (1981) noted that self-efficacy (as opposed to self-concept) is a situation-specific construct. Applying Bandura's theory to teaching, it can be seen that a teacher may have a high self-efficacy when it comes to teaching language arts and a low self-efficacy when it comes to teaching science. In working specifically with teachers, Shrigley (1983) showed that attitudes of teachers can be used to predict their behavior. In other studies by Stefanich and Kelsey (1989) and Hewson, Kerby, and Cook (1995), teacher's conceptions and attitudes were shown to have a strong influence on science teaching and learning. McDevitt, et al., (1993) called the effect of teachers' attitudes upon teaching critical.

In 1978, Weiss noted that elementary teachers spend an average of 90 minutes a day teaching reading versus only 17 minutes for science. Eleven years later, Stefanich and Kelsey (1989) stated that in elementary schools, less time is spent on science instruction than on any other major subject area. These results are not surprising, as studies by Hone (1970) and Cunningham and Blankenship (1979) show that teachers tend to perform those tasks that they feel competent in performing.

In a 1983 report, Feistritzer and Boyer noted that science concept understanding among elementary teachers was at "an undesirable, seriously low level" (p. 24). Similar results were found by Stevens and Wenner (1996) in their study of preservice teachers who were particularly concerned that preservice teachers with low knowledge bases were, never-the-less, relatively optimistic about their abilities to teach science. Feistritzer and Boyer (1983) found that many elementary teachers dislike, and do not understand, science.

McDevitt, et al., (1993) noted that children in the United States are not receiving adequate instruction in science or in mathematics, at either the elementary or high school level. They summarize that one reason for this lack of instruction is the poor preparation on the part of teachers. Anderson and Roth (1989) found that teachers with poor training in science rely on lecture and memorization rather than concept understanding. Osborne, Bell, and Gilbert (1983) noted that science taught in schools is often a mixture of the teacher's own views and textbook quotations.

One of the three premises upon which the 1996 Report of the National Commission on Teaching and America's Future, *What Matters Most: Teaching and America's Future,* is based is, "What teachers know and can do is the most important influence on what students learn" (p. 6). Victor (1962) and Dobey and Schafer (1984) found that many elementary teachers were reluctant to teach science as they felt that they had little knowledge of science content and science processes. Yet Young and Kellogg (1993) found that elementary education majors often take the minimum number of science courses possible. Although many complained about the lack of hands-on methodology, they did not enroll in laboratory courses when not required to do so. This could be, however, because these students saw little relationship between college science laboratories taught in the traditional manner and elementary science hands-on activities.

Surprisingly, other studies have refuted the idea that more science knowledge would result in a better attitude about teaching science. Shrigley (1974) found only a low correlation between science knowledge and attitude towards science. Feistritzer and Boyer (1983) found no relationship between the number of college science courses taken by teachers and their attitude toward science. Later Stephans and McCormack (1985) actually found a negative correlation between science concept knowledge and self-efficacy as did Wenner in 1993. In what should reignite an appraisal of the usefulness of traditional college science courses to elementary preservice teachers, Stevens and Wenner (1996) found a significant correlation ($p<.01$) between students' knowledge of science and the years of high school science courses taken, but no significant correlation between science knowledge and formal college science instruction. They also found no significant relationship between subject-matter knowledge and willingness to teach.

Westerback and Long (1990) showed that increased content knowledge, given through science and mathematics courses specifically designed for experienced master elementary teachers, can reduce the teachers' anxiety about teaching science and math. McDivett, et al (1993) got similar results when preservice teachers were enrolled in specially-designed and coordinated science, mathematics, and education courses. Their subjects significantly improved their attitudes toward science and mathematics teaching and became far more eager to teach science and mathematics than were their control subjects. Westerback and Long (1990) maintained that teachers who are comfortable with science are not only likely to devote more time to teaching it, but that they will do that teaching with more creativity.

Scharmann and Orth Hampton (1995) believe that a well-designed science methods course can improve the science teaching self-efficacy of preservice teachers and they argue that instructors of science methods courses should not leave self-efficacy development to mere chance.

Ramey-Gassert and Shroyer (1992) summarized numerous studies by stating that it appears that elementary teachers' poor self-efficacy has resulted in a science anxiety, poor attitudes toward science, and in an unwillingness or hesitancy to spend time teaching science. Because of its importance, Ashton (1984) argued that developing teacher self-efficacy should be incorporated into preservice teacher preparation programs.

ALTERNATIVE CONCEPTIONS OF SCIENCE

The last fifteen years have seen many studies on the problems associated with children and adults holding misconceptions or alternative conceptions of science. Although the term misconception is in common usage among educators today, the word is disliked by some because of its connotation as being a wrong idea. The more neutral term, alternative conception, was proposed by Hewson and Hewson (1983) and is used in this study. Nussbaum and Novick (1982) stated that alternative conceptions may play a crucial role in learning by interfering with science comprehension. Persons who hold alternative conceptions may have a great deal of difficulty learning new materials because their variant conceptions provide a faulty foundation for the formation of new insights.

It has been demonstrated in numerous studies that there are many common alternative conceptions held by school children and adults (Ault, 1982, Bar, 1989; Berg and Brower, 1991; Doran, 1972; Lightman, Miller, and Leadbeater, 1987; Sadler, 1987, Schoon, 1992; Wandersee, 1985). Schoon (1995) found that preservice elementary teachers often have the same alternative conceptions of the earth and space sciences as their prospective students have, and that many teachers have attributed their alternative conceptions to learning them in school.

Doran (1972) suggested that when planning science lessons, teachers should determine which misconceptions are prevalent among their students. In 1982, Posner, Strike, Hewson, and Gertzog proposed the widely acclaimed Conceptual Change Model; they maintained that in order for persons to change their conceptions, these persons must come to the belief that their existing conceptions are unsatisfactory, and that for new conceptions to then be accepted, they must be made intelligible, plausible and fruitful. Demastes, Good, and Peebles (1996) maintained that this model is useful in describing the ways that logical persons can experience wholesale conceptual change, but showed that there are a variety of pathways to learning concepts, not all of which fit into the Conceptual Change Model.

Even though alternate conceptions can be erroneous understandings, they are not necessarily the result of a lack of reasoning ability. Indeed, alternative conceptions are often the result of imaginative and very astute thinking (Ault, 1984). Some science concepts are simply harder for students to grasp than others. Hawkins (1978) coined the term "critical barriers" to refer to those very basic science concepts which may be quite difficult for the science novice to understand. Such concepts, including for example cosmological "up" and "down," must be comprehended before other more complex concepts can be understood. Huddle and Pillay (1996) noted that in the field of chemistry there are topics, including oxidation-reduction, that give learners great difficulty. These could also be called critical barriers.

It has been suggested that misconceptions are extremely resistant to change and often outlive teachers' efforts to eradicate them (Viennot, 1979 Hewson, 1985; Anderson & Smith, 1987, Brown, 1992). Atwood and Atwood (1997), however, showed that some alternative conceptions, such as alternative conceptions about the cause of day and night or the seasons, are not necessarily firmly held. They have shown that simple models can be used to induce conceptual change. Muthukrishna, Carnine, Grossen, and Miller (1993) argued that it may not be necessary to take the time to individually address alternative conceptions in order to eliminate them. Their study, using a videodisc curriculum in eighth grade classrooms, resulted in 90% of misconceptions being eliminated without the alternative conceptions being addressed.

The purpose of this study was to discover to what extent certain common alternative conceptions are held by preservice elementary teachers, to determine the relationship between science teaching efficacy and the number of alternative conceptions held, and to determine the relationship between science teaching efficacy and the holding of specific alternative conceptions.

METHOD

Data for this study was collected by means of a survey which was administered to 619 preservice elementary teachers during the first weeks of their science methods classes. All of the students were upper-level undergraduates (juniors or seniors) who had not yet begun their student teaching experience. The 10 university campuses participating in the study were in Rhode Island, Pennsylvania, Florida, Indiana, Arkansas, Kentucky, and North Dakota. Because of the preponderance of women in elementary education programs, no attempt was made to differentiate results by gender.

The Instrument

The instrument used for this study was refined following a pilot study of 110 preservice teachers. It consisted of two sections, one which measured science teaching efficacy and one which identified alternative conceptions of science. The first section was adapted from Enochs' and Riggs' (1990) Elementary Science Teaching Efficacy Belief Instrument (STEBI-B) which was developed specifically for preservice teachers. STEBI-A is a similar instrument designed for practicing teachers (Riggs & Enochs, 1990). STEBI-B is a Likert-type instrument with statements which are used to produce two subscale scores; the first subscale measures personal science teaching efficacy beliefs while the other measures outcome expectancy.

The first subscale, which measures one's personal science teaching efficacy beliefs, is based on statements such as:

> I will continually find better ways to teach science.
>
> I will find it difficult to explain to students why science experiments work.

The second subscale, which measures outcome expectancy, is based on statements such as:

> When a student does better than usual in science, it is often because the teacher exerted a little extra effort.
>
> Students' achievement in science is directly related to their teacher's effectiveness in science teaching.

A complete list of items in this instrument appears in Enochs' and Riggs' publication (1990).

Some changes in the Enochs' and Riggs' instrument were made for this study. In two items the word "some" was underlined, for that word is critical to a rating of these two items. The other change involves the rating scale used for this study.

In Enochs' and Riggs' instrument, a 5-point rating scale of strongly agree, agree, uncertain, disagree, and strongly disagree is used. The scale was modified for this study using the following categories: strongly agree, agree, barely agree, barely disagree, disagree, strongly disagree. This scale reflects two changes, the removal of a middle (uncertain) category and the adding of two rating categories (barely agree, barely disagree). The use of an even number of rating categories is as common as is the use of an odd number of rating categories (those scales that often include a "neutral", "unsure", or "undecided" rating). The removal of the middle category sometimes improves the precision of measurement that an instrument provides. When respondents are forced into a non-neutral selection, they are encouraged to think about items to which they might easily have responded "neutral."

Wright and Masters (1982) comment:

> A common practice for dealing with statements which are neither liked nor disliked in attitude questionnaires is to provide a "neutral" alternative. But this practice has not been universally accepted, and there has been extensive discussion of the misuse of the neutral category by respondents who do not which to participate (p.16-17).

The increase in the number of response categories for this study also confronts a common problem in rating scale analysis. If respondents use a wide range of a scale's categories (after recoding for reverse direction items), then the rating scale is helping to provide accurate measures regarding the attitudes of respondents. However, if only one or two categories are used, then in effect the other rating categories are not contributing to the measurement of respondents. Data from the pilot study with 110 preservice teachers using the revised measurement scale indicated the following rate of selection for each category: 10% strongly agree, 44% agree, 22% barely agree, 11% barely disagree, 10% disagree, 3% strongly disagree. This suggested that the barely agree and barely disagree categories contributed to the measurement process. Andrich has discussed the issues of category ordering and their utility in a number of articles (1979, 1988, 1996a, 1996b).

The second section of the instrument was a multiple-choice test for common alternative conceptions of science. Following a format suggested by Gilman, Hernandez, and Cripe (1970), each of the questions in this second section of the instrument contained one correct, or scientifically acceptable answer, one common alternative conception, and other distracters to make a total of four options for each question. The questions covered concepts in the life, physical, and earth/space sciences. Each of the alternative conceptions chosen for this study, with one exception, had been shown by earlier researchers to be common among groups of subjects. See Ganiel and Idar (1985), Johns (1984), Lawrenz (1986), Ross, Smith, and Anderson (1983), Sadler (1987), Schoon (1992), Sequeira and Leite, (1991) and Webb (1992). The one exception, an alternative conception noted informally by one of the authors, accompanied a map of Antarctica and asked which direction was north. The alternative conceptions which were contained on the instrument are listed in Table 1. Readers interested in obtaining a copy of the instrument may request one from the authors.

Analysis Technique Utilized

The stochastic Rasch model (Rasch, 1960) was used to evaluate these data. This evaluation technique was selected because the ordinal attitudinal scales had to be converted to interval scales. A number of studies have been conducted that show how item response theory can be used to correct non-linear rating scales (Andrich, 1982; Rost, 1988). The basic stochastic model which can be used to convert raw scores of coded responses to true measures is presented in Wright and Masters (1982), Rasch (1960), Andersen (1973, 1977), and Barnddorff-Nielsen (1978).

This analysis method was also selected because (a) it allows an evaluation when respondents do not answer every item, (b) measurement errors of survey items and respondents are reported, and (c) idiosyncratic responses of students can be easily detected (Wright & Masters, 1982).

Mean attitudinal measures were calculated for the two subscales (outcome expectancy and personal science teaching efficacy belief). This analysis technique enabled the calculation of the mean measure on a linear scale. In addition, error of mean attitudinal measures was calculated for each respondent. Following the calculation of the mean measures for each respondent, the mean attitudinal measures for those correctly answering each content item were compared to the mean attitudinal measures for those selecting a particular common alternative conception. T-tests were conducted to compare self-efficacy measures and outcome expectancy measures with the number of alternative conceptions held.

RESULTS

Alternative or Misconceptions Held by the Participants

Results of the survey first indicated that the preservice teachers in this study had many of the same common alternative conceptions identified in earlier studies. Table 1 shows these common alternative conceptions, listed in order of acceptance, along with the percentage of participants in this study who identified them.

Table 1. Common Alternative Conceptions Identified by the Participants.

Alternative Conception	Percentage of participants

The sun is straight up at noon every day (as seen from their own U.S. latitudes)	93%
Summer occurs when the earth is nearer the sun	78%
The earth's shadow causes lunar phases	67%
Heavier balls fall faster than similar lighter balls	49%
Venous blood is blue	45%
Rusted iron weighs less than the iron weighed before rusting	41%
Any mineral that scratches glass is a diamond	32%
Objects dropped from airplanes hit the ground immediately below the point where they were dropped	32%
Venus, Mars, and Jupiter can only be seen with a telescope	29%
Plants get their food from the soil	26%
Electric appliances "use up" electricity	26%
North is towards the top of a map of Antarctica	26%

The alternative conceptions range in acceptance from the sun's being straight up at noon every day (as seen from the participants' own latitudes) accepted by 93% of the respondents to three alternative conceptions, plants getting their food from the soil, electric appliances "using up" electricity, and North being at the top of a map of Antarctica, each selected by 26% of the participants.

Science Concept Knowledge and Science Teaching Efficacy

The number of science concepts correctly identified was compared to measures using the two subscales of the revised STEBI-B instrument. The results are shown in Tables 2 and 3. Differing N values across scales in the tables which follow are the result of individuals misfitting (using the scale in an unpredictable manner). Absolute numerical values of the efficacy measures are not comparable to the absolute numerical values of the outcome measures as the two subscales define different metrics.

Table 2. Self-Efficacy by Number of Scientific Concepts Known

Number Correct	N	Efficacy Measure	SD
0	1	+4.14	None
1	7	+1.37	1.81
2	28	+1.23	1.18
3	60	+1.21	1.38
4	101	+1.24	1.16
5	113	+1.33	1.05
6	113	+1.40	1.11
7	65	+1.32	1.11
8	48	+1.46	1.08
9	19	+2.27	1.89
10	11	+2.11	1.71
11	3	+2.77	2.13
12	0		

Table 2 shows the self-efficacy measure of students presented as a function of science concept items correctly answered, with self-efficacy measures reported in logit units. A more positive self-efficacy measure indicates a more positive view with regard to self-efficacy. Those with a very high number (9 or more) of correct answers seem to have a very positive belief in themselves.

Table 3. Outcome Measure by Number of Scientific Concepts Known

Number Correct	N	Outcome Measure	SD
0	1	+.39	None
1	7	+1.10	1.12
2	26	+.62	1.09
3	60	+.95	.85
4	94	+.85	.91
5	116	+.95	.93
6	114	+.90	1.00
7	68	+.68	.82
8	51	+.85	.75
9	17	+1.03	.88
10	10	+1.00	.43
11	4	+1.25	1.23
12	0		

Table 3 shows the outcome measure of students presented as a function of science concept items correctly answered, with outcome measures reported in logit units. A more positive outcome measure indicates students more likely to agree to the set of outcome expectancy items. (e.g. The group of four students with an outcome measure of +1.25 had the greatest tendency to agree with items defining this subscale, thus they as a group have the most positive feelings regarding outcome expectancy.)

T-tests were run to compare the self-efficacy and outcome expectancy measures to the number of science concept items correctly answered and the number of indicated alternative conceptions. Table 4 shows the results of the T-test of science content items correctly identified compared with the measures for self-efficacy and outcome expectancy. More positive logit measures again mean a more positive view with regard to outcome expectancy.

Table 4 shows that the students with the greatest number of correct answers (8 or more) had significantly higher (stronger) self-efficacy measure than those with fewer correct answers (3 or fewer). The students with the higher number of correct answers have an outcome expectancy mean measure that is also more positive, however the difference is not statistically significant.

Table 4. T-test on the Number of Science Concept Items Answered Correctly versus Self-efficacy and Outcome Expectancy

Science Knowledge versus Self-Efficacy

	Answering 3 or fewer correct answers:		
N = 96	Mean = +1.27	SD = 1.37	Std error = 0.14
	Answering 8 or more correct answers:		
N = 81	Mean = +1.79	SD = 1.46	Std error = 0.16
	Assuming unequal variances Prob>|T|	0.0153	

Science Knowledge versus Outcome Expectancy

	Answering 3 or fewer correct answers:		
N = 94	Mean = +0.86	SD = 0.94	Std error = 0.10
	Answering 8 or more correct answers:		
N = 82	Mean = +0.92	SD = 0.76	Std error = 0.08
	Assuming unequal variances Prob>|T|	0.6079	

Alternative Conceptions and Science Teaching Efficacy

As one of the primary purposes of this study was to determine what, if any, relationship existed between the holding of alternative conceptions of science and science teaching efficacy, the number of alternative conceptions of science selected by the participants in this study was also compared to the self-efficacy and outcome expectancy subscales of the revised STEBI-B instrument. The results are shown in Tables 5 and 6.

Table 5 shows the self-efficacy measure of students presented as a function of common alternative conceptions selected, with self-efficacy measures reported in logit units. A more positive self-efficacy measure indicates a more positive viewpoint.

Table 5. Self-Efficacy Measure by Number of Common Alternative Conceptions Held

Number of Alternative Conceptions Held	N	Efficacy Measure	SD
0	0		
1	2	+3.95	1.39
2	16	+1.67	1.71
3	45	+1.48	1.28
4	56	+1.34	1.49
5	141	+1.53	1.07
6	130	+1.26	1.04
7	92	+1.24	1.21
8	52	+1.46	1.47
9	27	+1.17	1.06
10	7	+1.08	.97
11	1	+1.10	None
12	0		

No clear pattern emerges from these data although the group of 2 students who had identified only one common alternative conception had the highest self-efficacy measure. Typical individual person measure errors for this scale were on the order of .38 logits.

Table 6. Outcome Measure by Number of Common Alternative Conceptions Held

Number of Alternative Conceptions Held	N	Outcome Measure	SD
0	0		
1	2	+1.65	1.56
2	15	+.98	.69
3	48	+.74	.67
4	59	+.89	.89
5	141	+.86	.96
6	124	+.82	.92
7	95	+.92	.98
8	46	+.97	.83
9	29	+.67	.77
10	7	+1.26	1.20
11	2	+2.06	1.81
12	0		

Table 6 shows the outcome expectancy measure of students presented as a function of common alternative conceptions selected, with outcome measures reported in logit units. A more positive outcome measure indicates students more likely to agree to the set of outcome expectancy items. No clear pattern emerged from these data. Typical individual person measure errors for this scale were on the order of .40 logits.

Table 7 shows the results of the T-test of the number of alternative conceptions selected compared to the students' scores on self-efficacy and outcome expectancy.

Table 7. T-test on the Number of Common Alternative Conceptions Selected versus Self-efficacy and Outcome Expectancy

Alternative Conceptions versus Self-Efficacy			
Identifying 3 or fewer common alternative conceptions:			
N = 63	Mean = +1.61	SD = 1.45	Std error = 0.18
Identifying 8 or more common alternative conceptions:			
N = 87	Mean = +1.34	SD = 1.31	Std error = 0.14
Assuming unequal variances Prob>∣T∣ 0.24			
Alternative Conceptions versus Outcome Expectancy			
Identifying 3 or fewer common alternative conceptions:			
N = 65	Mean = +0.83	SD = 0.71	Std error = 0.09
Identifying 8 or more common alternative conceptions:			
N = 84	Mean = +0.92	SD = 0.86	Std error = 0.10
Assuming unequal variances Prob>∣T∣ 0.51			

Neither the self-efficacy nor outcome expectancy means of those students who selected three or fewer of the common alternative conceptions was significantly different from the self-efficacy or outcome expectancy means of those who selected eight or more of the common alternative conceptions.

Specific Alternative Conceptions and Science Teaching Efficacy

In addition to determining whether the *number* of alternative conceptions of science selected by participants was related to measures of science teaching efficacy, another purpose of this study was to ascertain whether the holding of any *specific* alternative conceptions were related to these measures. Thus, the mean efficacy measures for those correctly answering each content item were compared to the mean efficacy measures for those selecting the common alternative conception.

Table 8. Specific Common Alternative Conceptions Related to Lower Feeling of Self-Efficacy

Alternative Conception
That planets can be seen only with a telescope. (p = .03)
That dinosaurs lived at the same time as cave-men. (p = .02)
That rusty iron weighs less than the iron that it came from. (p = .07)
That electricity is used up in appliances. (p = .03)
That North is towards the top of a map of Antarctica. (p = .00)

Results concerning the relationship of specific (as opposed to how many) alternative conceptions and efficacy showed that those persons who held five alternative conceptions were significantly more likely to have a *lower* feeling of self-efficacy.

DISCUSSION

This study adds a new dimension to Shrigley's work (1974) which found a low correlation between science knowledge and attitude towards science, and Stephans and McCormack's (1985) and Wenner's (1993) work which found negative relationships between science knowledge and science teaching efficacy. The use of Enochs' and Riggs' STEBI-B instrument, designed specifically for preservice teachers and made available since the above studies, allowed the authors to look for correlation between science knowledge and both self-efficacy and outcome expectancy, rather than simply a knowledge-attitude relationship. In this survey, those with the highest knowledge scores (8 or more correct) had very high self-efficacy scores, significantly higher than those with low scores (3 or fewer correct). Outcome expectancy results for those with the highest knowledge scores were, as in Shrigley's study, not significantly higher than those at the low end of the scale.

Results of this study have shown that the holding of alternative conceptions of science is still a problem among those preparing to become elementary teachers. Despite the great amount of work done in the past 20 years to identify common alternative conceptions and to devise means of dealing with alternative conceptions in the classroom, students are still leaving high school and college science courses carrying many alternative conceptions with them.

The holding of alternative conceptions of science has been found to interfere with learning. Nussbaum and Novick (1982) summarized numerous studies concerning the effects of alternative conceptions by stating that they may play a crucial role in learning by interfering with science comprehension. Persons who hold alternative conceptions have difficulty learning new materials because their variant conceptions provide a faulty foundation for the formation of new insights. To these persons, science may seem confusing or incomprehensible because of the discomfort caused by the cognitive dissonance which results from perceiving scientific phenomena which do not support already held alternative conceptions of science. This study found that the holding of certain specific alternative conceptions was associated with those persons of low self-efficacy. These alternative conceptions were:

That planets can be seen only with a telescope.

That dinosaurs lived at the same time as cave-men.

That rusty iron weighs less than the iron that it came from.

That electricity is used up in appliances.

That North is towards the top of a map of Antarctica.

The question naturally arises, why are these alternative conceptions related to lower self-efficacy, and not the others? The answer may lie in the fact that these five alternative conceptions are each fundamental barriers to a full understanding of their respective sciences; they are, using Hawkins' (1978) terminology, "critical barriers." Persons who believe that planets can be seen only by using optical instruments have never recognized the brilliant Venus or Mars as the evening "star" and cannot fathom how ancient peoples differentiated these planets from stars which were fixed in their constellations. The majority of persons holding this alternative conception also believed that the sun is straight up at noon every day, that summer occurs when the earth is nearer the sun, and that the earth's shadow causes lunar phases, the three most commonly selected alternative conceptions used in this study.

A person who believes that dinosaurs lived at the same time as cave-men has not firmly fixed Mesozoic life of 60 - 100 millions years ago within the geologic time scale. Undoubtedly, some of the participants in this study, believing in catastrophism or creationism, do not acknowledge the geologic time scale. Either person might have difficulty understanding or explaining to others the time parameters of evolution, plate tectonics, or the expansion of the universe. Similarly, the understanding that an iron nail gains weight as it rusts and that electricity is not "used up" in light bulbs or other appliances is basic to the understanding the concepts of mass and chemical change in chemistry and the study of energy in physics.

This study may provide evidence that the holding of certain alternative conceptions of science by preservice elementary teachers may cause a lower self-efficacy with regards to the teaching of science. It appears that because the holding of alternative conceptions of science often interferes with the learning process, the participants in this study holding them might have to struggle to understand scientific phenomena presented in science courses and would, as a result, feel less able to teach science to others.

Outcome expectancy was not affected by the holding of these alternative conceptions. Participants who had the above alternative conceptions and lower self-efficacy could, never-the-less, agree with statements on the STEBI-B instrument such as:

> Students' achievement in science is directly related to their teacher's effectiveness in science teaching.

These preservice teachers simply could not see themselves as being effective science teachers.

CONCLUSIONS

That preservice teachers hold many alternative conceptions of science should not be surprising. Only recently have school textbooks begun to address alternative or misconceptions that students might have. As most current classroom teachers had completed their teacher preparation programs before the advent of much misconceptions research, It can be assumed that few teachers today know much about the holding of alternative conceptions and so do not plan instruction with alternative conceptions in mind.

Recognizing that there may be many causes of a low self-efficacy among preservice elementary teachers with regards to teaching science, the data presented in this study may suggest that one of those causes might be the holding of certain alternative conceptions of science. The authors believe that, although most persons are comfortable with their own alternative conceptions of science because they believe them to be true, the holding of these alternative conceptions often interferes with the learning process, resulting in cognitive dissonance, which in turn may result in lowered belief in one's own abilities.

Critical Conceptions of Science

This study may show that not all alternative conceptions are of equal importance to the science educator. Some alternative conceptions may be important only to a small segment of today's science teachers; holding these "wrong" ideas simply does not greatly interfere with a person's ability to cope in today's world or even to learn more science. However, other alternative conceptions, may indeed be barriers to learning more science, learning about science, and perhaps appreciating science, and feeling good about one's own abilities to teach science. If so, these "critical conceptions" should be given more time in science classes. It is more important for students to come to a full conceptual understanding of these basic tenants, than to broadly, but superficially, cover much science content.

The authors believe that more study is necessary to find other critical alternative conceptions which may result in poorer self-efficacy and to determine whether these same alternative conceptions are associated with poorer attitudes about science by students in general. If so, teachers and teacher educators should place greater emphasis on learning these basic concepts of science upon which the learning of more science, and the appreciation for that science, may be based.

If the understanding of some science concepts can be shown to have a direct relationship to students' greater appreciation for, and ability to learn, science, and conversely, certain alternative conceptions can be shown to have a direct relationship with, or perhaps even cause, poorer appreciation for, and hamper the learning of science, then teachers and teacher educators need to place a greater emphasis on the understanding of these basic concepts.

Driver (1991) argues that K-12 teachers need to teach in a manner which takes into account children's extant ideas about science. Clearly, teacher preparation programs must not only prepare preservice teachers to help their students overcome alternative conceptions, they must also address the alternative conceptions of science held by their own teacher candidates. This may not only help break the cycle of alternative conceptions being perpetuated in the schools, but may help to improve the self-efficacy of the teachers themselves.

Scharmann and Orth Hampton (1995) argue that instructors of science methods courses should not leave self-efficacy development to mere chance. While modeling methods of teaching science to help their preservice teachers develop good, sound teaching practices, these instructors must also take into account that which is already known by their students and help them build upon what they already know. Instructors should help their preservice teachers confront their own alternative conceptions so that they can, in turn, help their future students confront their's.

Rammey-Gassert and Shroyer (1992) maintain that purposeful selection of science experiences can improve science teaching self-efficacy, and resultant attitudes about science and science teaching. Recognizing that the taking of traditional college science courses does not always affect students' understanding of science (Stevens and Wenner, 1996), methods instructors need to be sure that students leave their classes with a sound understanding of basic concepts in science such as the relationship of the earth to the sun and moon, the relative size and scope of the solar system and universe, the relationship of humans to earth history, and the relationship of electricity to electrical appliances.

An ideal way to do this may be through specially-designed content courses such as those described by McDivett, et al, (1993) where content courses were taught using methods that related concepts, avoided excessive lecturing and memorizing, and built upon students' experiences, paying particular attention to science concept development and the overcoming of alternative conceptions. If this cannot be done in science content courses, then it must be done in the science methods course

As self-efficacy has such an important relationship to teaching and student achievement, it is therefore important for educators to find other causes for poor self-efficacy. In spite of the fact that what causes poor or good self-efficacy in one person may not do so for another, and that many causes may work together to promote good or poor self-efficacy, it behooves educators to ferret out those attributes which can contribute to teachers' beliefs about science and science teaching.

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