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ABSTRACT

This study investigated the effect of three specific hands-on teaching strategies on the attainment and alteration of preservice elementary teachers' conceptions about earth-sun-moon relationships. The subjects (n=76) were enrolled in an elementary school science methods course. The descriptive nature of this study explored: (1) the effect of two instructional strategies--those using models versus those not using models--on preservice teachers' abilities to develop models to explain the occurrence of the lunar phases; and (2) whether spatial skills and reasoning levels interact with the ability to develop explanatory models. The results of the study suggest that models do have an effect. The group using only mental models did not show any significant change from pretest to posttest on the retention test. The group using physical models had significant categorical shifts from pretest to posttest. No significant interaction between spatial ability and model development was found. Results also suggest that concrete manipulated models appear to work best for novel situations, but that the type of models used in teaching abstract phenomena should be carefully determined. The paper concludes with several recommendations for further study. Contains 26 references. (PR)

The Effect of Teaching Strategies Using Models on Preservice Elementary Teachers' Conceptions about Earth-Sun-Moon Relationships

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"Utmost importance to good teaching is the ability to probe the understanding of the learner."
(Fosnot, 1989, p. 2)

Introduction

Many concepts in science are not visible or are difficult to see as a complete system or structure--the atom, the earth-sun-moon system, eroded rock layers, to name a few. To help understand "invisible" or partially visible scientific phenomena, one can mentally construct a model of that which cannot be observed directly. Each constructed mental model becomes a mental visualization or picture of the phenomenon within the space it occupies and the space that surrounds it. This model can be mentally manipulated such as through rotation or altering one's point of view. As a result, a useful and sometimes essential science skill is the ability to visualize spatially. However, there is a risk. Individual mental constructions can lead to alternate conceptions of phenomena--conceptions which are counter to the currently accepted scientific descriptions or explanations.

A consistent topic in elementary textbooks concerns the phases of the moon. To understand the abstraction of the phases of the moon, one must be able to mentally visualize the earth-sun-moon relationship. It is proposed there are special spatial skills needed for students to construct a mental model of this system. One must be able to have an "astronaut-view" (external perspective) of the system and/or one must be able to place him or herself in the center of the system (internal perspective). One must know that the viewing position is relative to how other parts of the system appear--shape, size, distance. One must be able to mentally rotate and/or manipulate visualized objects. All or part of these skills are needed for a student to create a viable mental visualization of the apparent cause of the phases of the moon.

In this sense, mental visualization is synonymous to projective spatial structures. These structures are constructed by keeping constant the topological constraints, such as openness-closedness, position, shape, and boundary, and mentally projecting the topological structures onto a spatial field in an arrangement in relation to the observer's point of view. The objects are no longer viewed in isolation but rather are considered in relationship to a point of view (Piaget & Inhelder, 1956). This ability to project objects or patterns spatially and infuse point of view manifests itself in projective conceptualizations (Cohen, 1983).

There is evidence that preservice teachers (Callison, 1988; Cohen, M. 1982; Dai, 1990) and college non-science majors (Targan, 1988) have some difficulty with visualizing relationships of the earth-sun-moon and possess or develop error patterns which have been labeled as misconceptions. Prior knowledge of the preservice teacher can contribute to the diversity, intensity, or lack of a conception (Clough, Driver, & Wood-Robinson, 1987; Fisher, 1985; Smith and Anderson, 1985; Targan, 1988; Vosniadou and Brewer, 1987). Cooperative grouping, teacher coaching, and working as individuals may influence student concept understanding (Bransford & Vye, 1989).

Success in many science learnings is linked with the learner's spatial conceptual ability (Cohen, H., 1982). A lack of this ability can lead to students holding a set of misconceptions, incomplete conceptions, fragments of a conception, or no conception. To help their students with projective conceptionalizations, it is important that teachers already possess those abilities or grasp how to translate those abilities into a useful set of instructional strategies which combine spatial visualization with problem solving and knowledge construction--strategies which could best help students learn to visualize spatially and change or build their projective spatial conceptions.

The purpose of this study was to investigate the effect of three specific hands-on teaching strategies on the attainment and alteration of preservice elementary teachers' conceptual understandings of earth-sun-moon relationships. The seventy six subjects were enrolled in a methods course entitled "Science in the Elementary Schools" during the Fall semester of 1990. The descriptive nature of this study explored the effect of instructional strategies using models versus instructional strategies not using models on preservice elementary teachers' abilities to develop models to explain the occurence of the lunar phases. There was an attempt to explain what relationship spatial ability and logical thinking ability might have with the instructional strategies. Four questions drove the research. What influence did prior knowledge have on the subjects' ability to explain observations? Would the level of spatial ability contribute to the subjects' ability to explain observations? Would the level of reasoning ability affect concept completeness, conceptual change, or conceptual development? What effects would a specific instructional strategy using models have on the subject's ability to develop an explanatory model of the lunar phases.

Five major thrusts underpinning the research are embodied in: 1) premises of learning theory and current understanding of college student conceptual development; 2) the aptitudes of spatial ability, prior knowledge, and reasoning level and their relationship to conceptual attainment or development; 3) aptitude measurement instruments; 4) instructional strategies which effect conceptual change; and 5) constructivist teaching models.

"Knowledge is a human construction, and learning is a creative activity" (Narode, 1987, p. 11). The philosophy of constructivism provides the epistemological basis for the pedgogical assumptions within this study. Inherent to constructivist theory is that knowledge is gradually constructed by people, over time, in their attempt to make sense of the world (Confrey, 1990; Fosnot, 1989; Driver & Oldham, 1986; Inhelder & Piaget, 1958; Narode, 1987; Staver, 1986).

METHODOLOGY

Subjects were assessed for prior knowledge (Targan, 1988) , spatial ability (Guay, 1976), and logical thinking ability (Tobin and Capie, 1980) at the commencement of the study. Prior to treatment, the subjects participated in a lunar observation for one month. Randomly selected subjects were interviewed prior to treatment and followng the month-long lunar observation. Treatment was administered followed by a posttest for content knowledge (Targan, 1988). The same group of subjects were interviewed a second time. Two weeks after the posttest administration, the Targan instrument was administered as a retention test.

Treatment was administered to four intact laboratory groups with each intact group receiving a different treatment. The four treatments (instructional strategies) reflected four levels of mental abstractness (ranging from concrete to abstract) and two viewer perspectives (internal and external). Treatment strategies one, two, and three utilized physical models while the fourth treatment strategy required the subjects to develop a mental model in the absence of a physical model. Treatment strategy four (the control) was employed as a comparison.

TABLE 1

MODEL		PROPOSITIONS
Correct	1.	One half of the moon is illuminated by the sun.
	2.	From the Earth we see part of the illuminated half.
	3.	The relative positions of the Earth, moon, and sun determine the portion of the half we see.
	4.	The moon orbits the Earth.
	5.	The illuminated half of the moon faces the sun.
Alternate	1.	The moon orbits the Earth.
	2.	The phases of the moon were related to the shadow of the Earth falling on the moon (eclipse model); or the phases of the moon were related to the moon orbiting the Earth-sun combination (heliocentric).
	3.	The amount of the moon we see depends on how much of the shadow covers the moon's surface (eclipse); or the amount of the moon's surface blocked by the sun (heliocentric).
	4.	The amount of the moon we see depends on the relative position of the Earth-sun-moon.
Fragments		Holding elements not definitive of any particular model.
No Model		Not holding any of the correct or alternate propositions listed above.

Interview data were coded with a set of discipline propositions (Table 1) which support lunar phase model explanation. Interview data were also analyzed for incomplete conceptions or misconceptions and the possible sources for misconceptions.

The results of the Test of Logic:.l Thinking (Tobin & Capie, 1980) and the Purdue Rotation Abilities Test (Guay, 1976), and the posttest and retention measurements (Targan, 1988) supplied the quantitative data. Chi Square was performed on the treatment data to ascertain any differences between treatment group categories on the pretest and posttest and between categories on the posttest and retention test. Correlational procedures were used to describe the strength of any relationship between spatial ability and model explanation or logical thinking and model explanation.

RESULTS

The statistical analysis revealed a significant shift of categories within treatment groups one, two, and three (Table 2).

Table 2

GROUP	CATEGORY				
	Correct Model	Alternate Model	Fragments of Model	No Model	X^2 v = 3
Concrete-Internal n=18					8.77*
Pre-test	1	4	3	10	
Post-test	2	5	9	2	
SemiConcrete-External n=28					13.54***
Pre-test	1	2	7	18	
Post-test	5	2	16	5	
SemiAbstract-External n=16					10*
Pre-test	2	2	3	9	
Post-test	6	2	7	1	
Abstract-External n=14					3.89
Pre-test	1	5	6	2	
Post-test	4	5	5	0	

*$p < .05$. **$p < .01$. ***$p < 0.005$

In comparing categorical shifts of treatment groups to the control, only one comparison (group two, semi-concrete/external with abstract/external) was statistically significant (Table 3).

Table 3

POSTTEST COMPARISONS

TREATMENT GROUP	Correct Model	Alternate Model	Fragments of Model	No Model	X^2 v = 3
					3.82
Concrete-Internal	2	5	9	2	
Semiconcrete-External	5	2	16	5	
					3.76
Concrete-Internal	2	5	9	2	
Semiabstract-External	6	2	7	1	
					3.36
Concrete-Internal	2	5	9	2	
Abstract-External	4	5	5	0	
					3.25
Semiconcrete-External	5	2	16	5	
Semiabstract-External	6	2	7	1	
					8.42*
Semiconcrete-External	5	2	16	5	
Abstract-External	4	5	5	0	
					2.9
Semiabstract-External	6	2	7	1	
Abstract External	4	5	5	0	

(CATEGORY spans Correct Model through No Model.)

*$p < .05$.

Using the Spearman Test, correlations between posttest category designations and the Test of Logical Thinking (TOLT) (Tobin and Capie, 1980) indicated only one significant correlation (SemiAbstract-External). The negative correlation was significant at 0.0002. Correlations are found in Table 4.

Table 4
CORRELATIONS OF POSTTEST MODELS WITH TOLT

TREATMENT GROUP	TOLT
Concrete-Internal	0.38
SemiConcrete-External	0.12
SemiAbstract-External	-0.80*
Abstract-External	0.43

*p < .001

The posttest categories were correlated with the scores of the Rotation Abilities Test (Guay, 1976). No significant correlations were found between spatial ability and model development (Table 5).

Table 5
CORRELATIONS OF POSTTEST MODELS AND ROT SCORES

TREATMENT GROUP	ROT
Concrete-Internal	0.39
SemiConcrete-External	0.04
SemiAbstract-External	-0.28
Abstract-External	-0.35

Discussion

"Learning needs to be conceived of as something a learner does, not as something that is done *to* a learner" (Fosnot, 1989, p. 5).

The concept of lunar phases, their occurence, and how they occur is a very complicated one. There are concepts within concepts which lead to a depth of understanding about the relationships of the Earth-sun-moon. Learning is "an organic process of invention, rather than a mechanical process of accumulation" (Fosnot, 1989, p. 20). The interview process revealed in more detail the thinking of the subjects. It was through the interview process that the more unique notions surfaced; i.e., the moon and sun being the same body with one visible during the day and the other visible at night. Several alternate conceptions or incomplete conceptions noted and reported include: moon's rotation causes the phases, viewing the moon from different places on Earth would cause viewer to see different phases (even on the same day), orbital shape is an elongated oval, the moon and sun are "in" the Earth, Earth's shadow falling on moon causes phases, clouds might cause phases, sun gets between Earth and moon causing new moon or only allowing us to see some of the lighted portion, the Earth's tilt causes the phases, and the moon's tilt causes the phases.

The richness of the interview data supports the need for exploration of a person's thinking before making judgments about a person's understanding. Fisher (1985) submits that since "learning is an incremental process with understanding incomplete at every level, it is easy to draw incorrect conclusions from incomplete models. The generation of misconceptions is thus a natural and probably unavoidable part of the learning process" (p. 61). Many of the alternate conceptions found in this study are consistent with the literature. The notion of seeing a different phase from a different part of the globe is not documented within the literature. The astronaut viewpoint and orbital shape notions expressed are novel. The most common error held by college nonscience majors (Targan, 1988, and preservice teachers in the United States (Cohen, 1982; Callison, 1989) and in Taiwan (Dai, 1990) in explaining lunar phases was that the shadow of the earth caused the different phases. Many subjects in this study used an eclipse alternate model to explain lunar phenomena. Targan (1988) found that the largest category in his study consisted of students holding no conception. The largest category of this study was with students holding fragments of a model.

What effects would a specific instructional strategy using models have on the subject's ability to develop an explanatory model of the lunar phases. Data show significant positive categorical shifts within treatment groups one, two, and three [Table 2]. As chi square procedures only indicate whether at least two categories differed from pretest to posttest, the weakness lies in not being able to identify what categories shifted. Of note is treatment group four (the control) which did not show any significant categorical shift. One interpretation is that the treatment did not have a negative effect.

When comparisons of the posttest to the retention test were subjected to Chi Square, no significance within the treatment groups was found. This could suggest categorical stability within each treatment group over time although the time frame was only 13 days.

Knowledge is individually constructed, active, and dynamic. It is relative to the learner (Narode, 1986). Therefore, all subjects' categorical placements were charted to look for patterns and trends. The general trend suggested subjects move from no model through fragments of a model to developing a model. In the trend description no subject went from having a correct model to having no model. Posner, Strike, Hewson, and Gertzog (1982) presented conditions under which conceptual change would occur. Only one subject's conceptual behavior measured as holding an alternate model on the pretest, holding no model on the posttest, and holding fragments of a model on the retention test does not appear to support the Posner, et al conditional descriptions. The first condition of "dissatisfaction with existing conceptions" (p. 214) is supported by the posttest measurement for this subject. However, this subject did not express, on either the posttest or the retention test, any discernible explanatory model (lunar phase concept). Conditions two, intellibility, and three, plausibility, were not supported as the subject did not suggest a new conception. Perhaps the fourth or fruitfulness condition is affecting the subject's ability to formulate an explanatory model. One could argue that, for this subject, the whole idea of lunar phases does not provide a possibility for fruitful research. However, at least one other notion that of time and the process of change could be argued. It takes a long time to change. This study covered four months of time. Perhaps this subject needed more time. Perhaps this subject is in the process of change and, therefore, not exhibiting the conditions delineated by Posner, et al. Perhaps the measurements taken within this study captured this subject in the conceptual development process rather than in the conceptual change result. Perhaps this is an outlier subject and just should be noted as such. At the very minimum, the results suggest a need for more study of the relationship of conceptual development and time

Within the type of measurement used it is not possible to detemine with a high degree of confidence whether the treatment affected the subjects who held no model on the pretest. Novices may have had a minimal-to-no prior exposure to the content and they may lack retrieval mechanisms. Perhaps the strongest influence is the first time focus on the phase idea. If one has never thought about a phenomenon before, just the exploration of new content could have more weight than any treatment. During the interview process, some subjects' comments supported the novelty premise. Another influence might have been the interview process itself. The interview provided individual attention and allowed twenty three subjects to reflect upon and confront their ideas regarding lunar phases. As Narode (1986) states: "All knowledge is ultimately self-referential and all self-referential knowledge is relative--not absolute. It is constructed individually. Consequently, students need individual attention" (p. 32).

What influence did prior knowledge have on the subjects' ability to explain observations? Fosnot (1989) offers that "knowledge consists of past constructions" (p. 19). Narode (1986) postulated that "a student's epistemology shapes the attitude toward, and conceptions of, both the content and the process of learning" (p. 32). Of the subjects interviewed, four subjects held correct models (n=5) on the pretest and remained in the correct model category throughout the study. The fifth subject holding a correct model on the pretest shifted to fragments of a model for the remainder of the study. The category stability appears to support the strong influence of prior knowledge. Of the interviewed subjects who held an alternate model on the pretest (n=13), three shifted to a correct model on the posttest; six shifted to fragments of a model; one to no model; and three stayed with an alternate model on the posttest. Of the six interviewed subjects who held fragments of a model on the posttest and alternate models on the pretest, 2 shifted back to an alternate model on the retention test and 2 did not take the retention test. This pattern perhaps represents the tenacious qualities of prior knowledge as described by Driver & Oldham (1986), Fisher (1985), Posner, Strike, Hewson, & Gertzog (1982).

The instrument used to assess prior knowledge was the Targan Test (Targan, 1988). In qualitative research the descriptive process is personalistic which is manifested in no one person operating exactly like another. Within that context an instrument's codes should be specific and clearly defined to avoid serious problems of reliability. Agreement on description or composition of explanations rather than on frequency is the basis of observer or coder reliability. The inter-coder reliability for the Targan Test was high [$\pi = 0.839$] suggesting that this instrument is reliable in assessing categorical description and placement; therefore supporting observer congruency and internal reliability. The issue of external reliability in descriptive studies is defined in terms of replicability (LeCompte & Goetz, 1982). Without precise categorical identification, thorough strategy description, and clearly defined data collection procedures; replication is impossible.

As this study is an effort to record the process of change, the Targan Test (Targan, 1988) did afford some limitations. The instrument was successful in categorical placement indentification. However, in terms of replicability and further measurement there is a twofold need for developing a more sensitive instrument: 1) to critically assess where, how, and when conceptual shifts occur and 2) to assess the degree of conceptual shift attributable to treatment. Perhaps revising the Targan instrument to become more sensitive to identifying conceptual development or change would be an appropriate place to begin.

Would the level of spatial ability contribute to the subjects' ability to explain observations. A major portion of the research problem was based on the principles of spatial abilities. Although the correlation data between spatial ability and model development was not significant, the subjects interviewed made statements relating to spatial abilities. Subjects within treatment group four expressed they would have liked to have had materials to make models. During the treatment within group four, subjects attempted to use available materials within the room to make a model (i.e. soda cans, pencils, notebooks, and their own bodies). This behavior appears to endorse the need for concrete objects to define a space and to manipulate within a space an individual's mental ideas. Perhaps it is just extremely difficult to perform spatial operations mentally. Some interviewed subjects exhibited frustration with moving from internal to external perspectives. Moreover astronaut panoramas were always expressed from an above the system viewpoint. Both of these notions could imply limitations of or a lack of flexibility in mental spatial manipulations. Therefore, although there was no significant correlation found, the interview data revealed that subjects not only used spatial skills to explain lunar phenomena but also needed spatial abilities for those explanations.

Would the level of reasoning ability affect the subject's ability to explain observations? Subjects were given the Test of Logical Thinking (Tobin & Capie, 1980) to ascertain their level of logical thining. The findings were analyzed for any prior significant between treatment group differences. None were found. The post treatment categories within each treatment group were correlated with the TOLT scores. Treatment strategy groups one, two, and four did not show a significant correlation between reasoning ability and model explanation. There was a significant correlation beween logical thinking ability and model development for subjects in treatment strategy group three. The negative correlation describes that those students who held a model had higher TOLT scores. This relationship supports the research question. Since the relationship was only significant for one treatment group, the strength of the relationship across the groups is in jeopardy. If there was an effect of reasoning ability on a person's ability to explain observations, why wouldn't a significant relationship appear within all groups? There was no attempt to answer that question within the bounds of this study. Correspondingly the question suggests a need for more research of this variable and its relationship to model development and/or phenomenological explanation.

Implications for Instruction

> Epistemology matters in the classroom. A student's epistemology shapes the attitude toward, and conceptions of, both the content and the process of learning. It determines whether the student is a rote memorizer or a conceptualizer. Furthermore, the teacher's epistemology has direct bearing on the classroom he or she creates and on the epistemologies of the students. (Narode, 1986, p. 32)

In a study examining the use of examples to remediate misconceptions in physics, Brown (1992) concluded 1) the use of concrete examples can be an effective practice for accomplishing conceptual change, and 2) teachers need to help students develop visualizable, qualitative, mechanistic models of physical phenomena in order to make sense of more abstract principles (p. 30). The findings of this study are in concert with Brown by suggesting that physical models help a student explain abstract phenomena. Student construction and manipulation of models accompanied by verbal explanation aid the teacher by illuminating inconsistencies in the student's thinking and incompleteness of a student's conceptual understanding. The student's knowledge and experience coupled with the teacher's knowledge and experience influence the design of lessons and models employed in the classroom. As Brown (1992) submits "teachers need to be aware that examples which they find compelling may not be at all illuminating for their students." (p. 30). If a teacher has a shallow or incomplete understanding of a phenomenon, there is a risk of selecting inappropriate models. Additionally, in an attempt to create useable models, one could miss the dimensions of a model which could become a source for misconceptions (M. H. Cohen, personal communication, April 2, 1993). In other words, the epistemology of the teacher needs to be considered along with the student's epistemology (Narode, 1986).

As suggested by the results of this study, concrete manipulated models appear to work best for novel situations. However, the type of models used in the teaching of abstract phenomena should be carefully determined. Some concrete models may require the user of that model to employ thinking skills which are highly abstract. This, in turn, could create disequilibrium within the learner expressed as dislike for or discomfort with a perspective (external) thus resulting in the learner reverting to a more comfortable view (internal). The models in this study allowed the viewer an external perspective. As the sense of a phenomenon is internal and all individual explanations are the expression of an internal viewpoint, maybe an externally viewed model increases the complexity rather than providing a simple forum for explanation. All models used in this study asked the student to move back and forth between internal and external perspectives that perhaps set up a requirement for mental gymnastics beyond the subjects' capabilities.

The complexity within models is perhaps greater than teachers and educational materials acknowledge. Thoughtful consideration should precede model selection and utilization. One notion expressed by several interviewed subjects was that where you are on Earth would determine what phase you would see. Any model selected to explain phase phenomena should sustain an Earth perspective not a where-you-are-on-Earth perspective. The where-you-are-on-Earth notion may also tie to the issue of internal and external perspective mentioned previously. Models which demonstrate the motions of the Earth rotating on its axis, the moon rotating on its axis, and the Earth and moon as orbiting bodies could possibly dispel the where-you-are-on-Earth perspective. To recognize the conceptual dangers inherent within a phenomenon and to make judgments about models , teachers need a depth of content knowledge. The depth of content knowledge permits flexibility in thinking about conceptual models.

While investigating model complexity, limitations of any model should emerge. The known limitations of any model should be revealed and discussed either by the student during verbal explanation or by the teacher as part of the teaching strategy. In this study one limitation was the lack of attention to and employment of scale in the models. Interpretations of the dialogue of interviewed subjects suggest that attention to scale might have assisted the development of more correct propositions. Conversely, scale might have permitted subjects to realize their errors in their own model explanations, most especially the eclipse and heliocentric alternate models. Subject #2636 might have been helped by attending to scale within the models.

I What is your explanation for why the phases of the moon occur?

R - 2636 Because the moon is moving around the Earth and the Earth is rotating and the moon gets light from the sun. . . . The phases occur because of what we can see from Earth of the moon moving around the Earth.

I If that's the case would there be any time when the Earth would make a shadow on the moon?

R - 2636 I guess maybe I am being too logical here. But if the Earth was in between the sun and the moon I would think it would cast a shadow on the moon.

I Have you ever heard of that happening?

R - 2636 That would be an eclipse.

I [In an attempt to get the subject to review her thinking, the interviewer asked] So if the Earth is between the moon and the sun what phase of the moon do we see on Earth?

R - 2636 Dark.

I So you are saying it is an eclipse?

R - 2636 Well, no, because an eclipse doesn't happen that often. I don't understand why an eclipse only happens every once in a while. It has just got to be on the correct axis or something I don't know. [Subject was in a quandry over occurrence of an eclipse. Perhaps scale would have helped.]

A final issue related to this study and to instruction, which is essential to clarity in conceptual understanding, is to beware of false positives. False positives are responses that sound correct on the surface yet supported with incorrect notions. During the interview process, the interviewer heard the "right" words. However, once the subjects were questioned about the meaning of those "right" words, the meaning was absent or incomplete. One must listen to the responses of students and probe for greater explanation before judging the quality of the response. Interviewing is strongly recommended for classroom use as an assessment method.

Recommendations for Further Study

One recommendation is to develop more sensitive instrumentation or sets of procedures for assessing conceptual development. The instrumentation used in this study supports the need for more sensitivity. The initial thinking about a concept and the explanation of a concept may be uniquely tied to a conceptual group within a particular setting. Research should be conducted to determine clearly if there might be a consistent pattern between or among concepts and/or what concepts are contextually bound.

A second recommendation is to identify appropriate models which are specific to the concept to be investigated. Once the models have been identified they should be evaluated for limitations, complexity, and mental demands for the user. An alternative to this idea would be to develop a method to evaluate models so the practitioner could evaluate existing models or individually created models.

A third recommendation is to investigate the issue of scale. Although scale was not addressed in this study it should have been and is considered a limitation.

> The ranges of magnitudes in our universe -- sizes, durations, speeds, and so on -- are immense. Many of the discoveries of physical science are virtually incomprehensible to us because they involve phenomena on scales far removed from human experience.... magnitudes are far greter than we can comprehend intuitively.... Nevertheless, we can represent such magnitudes in abstract mathematical terms (for example, billions of billions) and seek relationships among them that make sense....[P]henomena can be understood at various levels of complexity, even though the full explantion of such things is often reduced to a scale far outside our direct experience. (American Association for the Advancement of Science, 1989, pages 130-131).

As suggested by the descriptions in this study, scale could possibly have made a difference in model development. Scale is important. Information is needed regarding the significance of different factors of scale. Are certain properties, of scale, concept or model specific? What influence does the level of understanding about scale have on specific concepts or models? Would measurement of a person's skill level or understanding of scale help the interpretation of scale's effects? At what point in the instructional process would various properties of scale have the most effect on the learner? What properties of scale are essential for model development and interpretation? The answers to these questions would, in part, lead to a more thorough knowledge of scale.

Conceptual growth occurs overtime and requires revisiting and reflection. "The construction of knowledge is subject to a psychogenetic study of the change in knowledge structures in humans in the course of their development. Cognitive scientists would benefit from developmental studies of children and adolescents" (Narode, .1987, p. 32). In addition to the issues cited above, it is recommended that the questions of this study be investigated over a longer period of time.

As noted in the discussion section, this study may have been the first exposure subjects had to Earth-sun-moon relationships. Since the subjects were preservice elementary teachers and studying Earth-sun-moon relationships is found within most elementary science programs, the study's descriptions suggest a need for a stronger match between content knowledge covered within general education requirements and content knowledge covered within elementary school science. A second implication for preservice elementary teachers preparation lies within the context of retrieval systems. Both of these ideas could be addressed through content courses specifically designed for the teacher and teacher preparation courses including and focusing on problem solving strategies. These recommendations are not new (Anderson, 1979). However, they are still needed.

Conclusions

The purpose of the study was to describe 1) if instructional strategies using models effect preservice elementary teachers' abilities to develop explantory models, and 2) if spatial skills and reasoning levels interact with the ability to develop explanatory models.

Within the population examined, it appears that models have an effect. The control group (Treatment Strategy Four) did not show any significant change from pretest to posttest to retention test. All three treatment groups had significant categorical shift from pretest to posttest. One delimitation lies within the inability to describe the nature of the categorical shift. The interview process revealed patterns of category movement from no model to fragments to model, from alternate model to fragments to correct model, and fragments to model. These patterns might suggest a continuum of conceptual development and cognitive structuring (Vosniadou & Brewer, 1987). However, further study would be needed to either reject or support these trends.

No significant interaction between spatial ability level and model development was found. Maybe direct attention to scale could have focused this variable. The interview data hint that there is a need for spatial ability to explain phenomena, however further study on this variable is needed. The role of logical thinking in model development was mc roblematic. Treatment group three was described as having a significant correlation between a higher TOLT score and developing an explanatory model. It is not clear why the other treatment groups did not have a significant relationship. This variable would need further study to more clearly describe its influence. Perhaps instrument selection was a factor.

Models do have an affect and need to be carefully selected. Although not within the scope of this study, the influence of scale needs further research.

A final conclusion stems from the interview data. As detailed in the discussion section, the interview reveals a depth and richness of detail which is rarely found outside of this process. The interview allows for probing specific ideas espoused by individuals and for assessing the scope of understanding.

Summary

"Meaningful learning occurs through reflection and resolution of cognitive conflict and thus serves to negate earlier, incomplete levels of understanding"

(Fosnot, 1989, p. 20).

Many findings reviewed in the literature are consistent with the descriptions detailed and recounted in the discussion section in this paper. Although supportive of other research, the findings reported only describe the population of this study. They are but a brief snapshot in time.

However, this study was most helpful in illustrating what still needs to be done. Further research is needed on the issue of scale, content specific models, and longer time frames. Instrumentation needs to be developed and tested to assess the nuances of conceptual development and change. Different populations need investigation. When all these recommendations are met, perhaps the role, utilization, and selection of models as well as the puzzling picture of teaching and learning will be more clearly revealed.

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