DOCUMENT RESUME

ED 465 523 SE 066 129

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TITLE Changing the "Ecosystem" of Preservice Math and Science Methods Classes To Enhance Students' Social, Cognitive, and Emotional Development.
PUB DATE 2002-02-00
NOTE 19p.; Paper presented at the Annual Meeting of the Eastern Educational Research Association (Sarasota, FL, February 27-March 2, 2002).
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Active Learning; Biological Sciences; Constructivism (Learning); Elementary Education; Higher Education; Mathematics Education; *Preservice Teachers; Science Education; Self Concept; *Teacher Education

ABSTRACT

This research examines the critical factors in a science/math methods course and its effect on the dispositions of preservice elementary education majors. In order to break the cyclical axiom that "teachers teach as they were taught," this study used a paired-t test design to indicate any significance. The preservice education majors indicated that they felt more prepared to teach developmentally-appropriate lessons in Life Science, Earth Science, Physical Science, and Astronomy. There was a development of a positive self-efficacy, which will have a great impact on the effectiveness of the new teachers. Constructivism as a theory of learning and teaching and as a significant factor in developing a heightened sense of self-efficacy was the theory used in the classes. In order to learn math and science, the learner must be active and engaged in the process. The notion of teaching science as a reading assignment and math as something to be learned in lecture is shown to be ineffectual and inefficient. (Contains 12 references.) (Author/MM)

Running head: CHANGING THE "ECOSYSTEM"

Changing the "Ecosystem" of Preservice Math and Science Methods Classes to Enhance Students' Social, Cognitive, and Emotional Development.

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Paper presented at the Annual Conference of the Eastern Educational Research Association

Sarasota, FL

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Abstract

This research examines the critical factors in a science/math methods course and its effect on the dispositions of preservice elementary education majors. In order to break the cyclical axiom that "teachers teach as they were taught," this study used a paired-t test design to indicate any significance. The preservice education majors indicated that they felt more prepared to teach developmentally appropriate lessons in Life Science, Earth Science, Physical Science, and Astronomy. There was a development of a positive self-efficacy, which will have a great impact on the effectiveness of the new teachers. Constructivism as a theory of learning and teaching and as a significant factor in developing a heightened sense of self-efficacy was the theory used in the classes. In order to learn math and science, the learner must be active and engaged in the process. The notion of teaching science as a reading assignment, and math as something to be learned in lecture is shown to be ineffectual and inefficient.

Review of Literature

An "ecosystem" is loosely defined as a community of entities totally dependent upon each other to function and grow as a whole. This research will identify the factors extant within a classroom and the factors affecting the social, cognitive, and emotional growth of the students. The interactions of the instructor and the students must actively enhance the growth and development of effective teachers. The understanding of teaching styles, organizational patterns, performance objectives, and degree of self-efficacy achieved by the students will determine the success of the teachers.

Understanding student perceptions about his or her own self-efficacy, a component of self-concept, and how it might affect academic achievement can provide significant implications in classroom instruction and instructional settings (Jinks and Morgan, 1997). Pajares (1995) maintains that how a student develops the factors that comprise and affect self-efficacy is important in analyzing the impact these elements have on a student and subsequent performance in educational settings. Stader and Gagnepain (2000) report that drastic improvement in school atmosphere, responsibility and relationship-building programs, through the use of mentoring by other students, help to increase self-efficacy. It was reported by Hoy and Hannum (1997) that there was a significant relationship between school and classroom organization and student achievement.

It is fundamental to the research that the development of a student's perceptions of self-efficacy and self-concept are the result of interaction with their environment. When students determine their own place in the environment in which they spend so much time, it is helpful to know the components of the environment (Bandura, 1986;

Bandura, Barbaranelli, Caprara, Pastorelli, 1996; Bong, 1998; Felsen, 1984; and Wray, Medwell, 2000).

Many colleges and universities have focused on changes that center on improving teaching and learning. In the past decade, we have seen a focus on teaching techniques in college classrooms, a movement that emphasizes active learning, the value of out-of-class learning, and the importance of assessment on college campuses. We have addressed the all-important issue of learning by college students without focusing on the all-important question of "how" our students learn academic material.

In relation to academics, hands-on inquiry learning has been shown to improve student performance in a number of studies (Frederick & Shaw, 1998; Mathis & Nakayama, 1988; and Tyler-Wood, Cass, and Potter, 1997). A study by Hicks (1998) found that inquiry based learning at a rural middle school for academically challenged students increased the number of those passing science classes by approximately thirty percent. Another study completed by Butta (1998) found that rural high school students participating in cooperative, hands-on instruction had a three percent higher grade point average than those participating in traditional science instruction.

While many studies focus on whether inquiry-based instruction improves science performance, few studies examine how it affects student attitudes related to science, particularly over the long-term. One longitudinal study examined the interest of students in science over several years by assessing both the achievement levels and attitude toward science of middle school students participating in a hands-on summer program with those who did not participate in the study. The program showed promising results. Gibson (1998) examined middle school students attending a two-week, hands-on science

workshop with students having similar science aptitude and interest in the subject area. The author found that students participating in the program had a more positive attitude toward science in general and continued to have a more positive outlook even while they were in high school. While both the control and experimental groups showed a decrease in interest over time, the experimental group demonstrated less of a loss.

The National Science Education Standards released four goals of science education in grades K-12. These are: (1) make sure students understand and experience the excitement of the natural world, (2) to use scientific processes to make decisions, (3) to be able to speak intellectually on scientific and technological topics, and (4) to increase their contribution to society by knowing, understanding, and being able to perform scientific skills (Yager, 2000).

Teachers have a great stake in all of these changes and the achievement of these goals. Yager (2000) says, "Teachers have an opportunity to cultivate and nourish their students' innate curiosity about the world" (p. 2). Teachers must find ways to teach students in the classroom that actively involve and challenge the students. The goals listed above also help in diminishing a teacher's own misconceptions and help the teacher assist students in applying scientific knowledge and skills.

In order to fully understand the relationship between self-efficacy and achievement, it is necessary to study three main implications for science teachers as described by Jinks, Lorsbach, and Morey (2000). These are: (1) that the science curriculum will be impacted, (2) that the mode of instruction will be impacted, and (3) that the forms of assessment will be impacted (Jinks et al. 2000). Jinks et al. (2000)

maintain that there will be a positive enhancement in self-efficacy when the content is presented in smaller segments and the concepts ascend in difficulty.

Lee (2002) discusses the widening of the achievement gap between Whites-Blacks and Hispanics-Whites on test scores. The author suggests several areas that must be examined and taken into account before one can empirically document the widening of the gap in achievement. These are areas cited by Bandura et al. (1996); Felsen (1984); Pajares (1995) and Bandura (1986) as areas that can be overcome and relegated as ineffectual on achievement by developing a positive sense of self -efficacy. These, according to Lee (2002) include: (1) the National Assessment of Educational Progress gap, (2) the poverty gap, (3) single household gap, (4) high school education gap, (5) college education gap, (6) alcohol gap, (7) illicit drug gap, (8) high school drop out gap, (9) crime victimization gap, and (10) advanced course gap. As reported by Lee (2002), these gaps are not directly related to equity. Nevertheless, these gaps should be taken into account to explain the widening of the achievement gap, which will affect teachers and policy makers of the near future.

To achieve autonomy for all students, Jinks et al. (2000) has listed some suggestions on how teachers can increase self-efficacy and, ultimately, student autonomy. They are: (1) provide opportunities to reflect on and assess how the students perform in science and identify criteria that students may believe affects their learning, (2) develop more problem-solving lessons, (3) ask the students to contribute to what they want in the science curriculum, (4) make sure lessons contribute to lifelong learning instead of being busywork, (5) provide opportunities for the students to collaborate, and (6) encourage more small group activities and individualized instruction (Jinks et al. 2000).

Schoenfeld (2002) exposes the facts that the poor, the African American, the Hispanics, and the Native /American students comprise a disproportionate amount of the students who drop out of mathematics at higher levels. This has a tremendous impact on their ability to complete higher education and to get and keep the careers of the future. According to Schoenfeld (2002), every American has the right to quantitative literacy. The implications of these findings on the profession of teaching are great, but attainable goals to overcome the implications are beginning to show results. The two primary activities that must happen are the design of a curriculum that is appropriate for the public being served and for professional development. Schoenfeld (2002) maintains that knowledgeable teachers who can sustain a stable curriculum that is designed to enfranchise all students by offering a practical and necessary mathematical education that will aid in the development of self-esteem and ensure quantitative literacy, is necessary if an educated population is going to succeed. Assessing knowledge should be carefully planned and communicated to stakeholders (parents and community) for the importance that literacy plays in the future of the students (Schoenfeld, 2002).

Jinks et al. (2000) also stipulates that self-efficacy hinges on accurate assessment. It is strongly suggested that teachers need to evaluate their students' self-efficacy beliefs by soliciting the following information: (1) ask how well do the students expect to perform in science, (2) ask if the students feel confident in their understanding and fully know what they have learned, and (3) ask if they think they are able to learn science (Jinks et al. 2000). Jinks et al. (2000) encourages teachers to initiate dialogue by asking students to give rationalizations about beliefs and ideas. Jinks et al. (2000) cites Bandura (1986) as having said that people will often change how they feel after they have

reflected on their behavior and thinking. Jinks et al. (2000) states that if low self-efficacy students are not allowed to revise their thoughts on science achievement then their self-efficacy will not change.

Bandura (1986), in formulating his original theory of self-efficacy, maintains that self-efficacy is influenced by four sources of information: (1) emotional arousal; (2) performance accomplishments; (3) verbal persuasion, and (4) vicarious learning. It must be noted that these sources may cause modification self-efficacy expectations.

An interesting example of this may be the student who enrolls in a physics class but is intimidated by math. By watching others work the problem, this person will experience vicarious learning. If the person works with another person to solve the problem, then the person is increasing self-efficacy through performance accomplishments. When the person perceives support and/or encouragement from others, then they are using verbal persuasion. Finally, the person solves a problem independently and lessens the anxiety about physics. This is an example of emotional arousal. Bandura (1986) maintains that because it involves personal master performance, accomplishments are the best measure of developing an increase in self-efficacy.

Luzzo, Hasper, Albert, Bibby and Martinelli (1999) suggests that further research should examine performance accomplishment and vicarious learning among younger participants and to more culturally and ethnically diverse groups. Research lacks empirical data on these groups. According to Luzzo et al. (1999), future studies should examine such interventions as "anxiety reduction strategies" and the skill of verbal persuasion.

The theory of constructivism is based on the assumption that there is an innate human drive to understand and/or make sense of the world. Rather than absorbing objective knowledge that is "out there," learners construct knowledge actively by assimilating new information and experiences into prior knowledge and experiences, constantly revising and reinterpreting old knowledge in an attempt to reconcile it with the new knowledge (Billett, 1996). The cognitive structures that learners build include "procedural" knowledge and "propositional" knowledge. Often neglected are dispositions that include but are not limited to attitudes, values, and interests that help learners decide: "Is it worth doing?"

Functional context, social context, and usefulness are other factors in the knowledge construction process. The process works best when it is embedded in a context in which new knowledge and skills can be put to a practical use. Thinking and learning research reinforces the idea that people learn better through interaction with others (Johnson and Thomas, 1994). Learning is a matter of personal and singular interpretation although it takes place within the social context. In addition, learning must be perceived as being useful to the learner. Emerging from the desire to understand and to construct meaning comes intrinsic motivation (Billett, 1996).

Using a constructivist approach, teachers are able to guide learning by promoting active inquiry, encouraging learners to question their basic assumptions, and coaching them in the process of construction. A constructivist teacher is more concerned with uncovering meanings than in covering prescribed material. Given the material cited in the literature review, understanding the self-efficacy level of undergraduate education majors is an important topic. The role that achievement plays as related to self-efficacy is

also an important topic of discussion. Understanding the connection between self-efficacy, hands-on science, achievement, and student development was the main goal of this research.

Methodology

Each class was designed to provide a model of the ecosystem reported in the literature. All activities and lessons were designed around a constructivist theory of teaching and learning. Much of the semester was spent in cooperative/collaborative groups with time built-in for self-talk and reflection. Groups self-selected themselves and changed membership often. The research component of the course was limited to scaffolding, hands-on, and inquiry lessons. Constructivism was a major topic.

An atmosphere of ease and motivation was evident. Dialogue between students and the instructors was usually based on observations of students' behaviors, work ethics, processes, and level of perceived difficulty. Critical thinking and divergent thinking were explored at every opportunity. The process of knowing how to do, rather than regurgitating facts and following a publisher's "cook- book" lab or demonstration was a primary goal. Multiple assessments were used to measure gains in learning. Authentic assessments with rubrics were used whenever possible. Talking about "why" something was done in class and how it could be done in a school setting were extremely worthwhile activities.

Reflective journals were kept daily to record the activities completed in class, the materials used in the activity, and, then, their evaluation and perceptions of the activity or lesson. They also wrote about how this lesson could be modified for a certain grade level

or how they would change the lesson to make it more comfortable for them in their teaching.

Peer teaching with reflections and peer evaluation helped ensure that pedagogy was being used correctly and that the lesson being taught was valid and worthwhile and, most importantly, developmentally appropriate for the intended audience. The students spent an entire semester totally immersed in a class that "did" science and math rather than being "taught" science and math.

Instrumentation and Research Design

A novel survey was created following an exhaustive search of the related literature. The survey was designed to assess the teaching style of the instructor and the learning styles of the students. Questions were asked to determine prior content knowledge, perceptions of the degree of self-efficacy, and readiness for the performance objectives as defined by the teacher.

The survey was awarded construct and content validity by a panel of learned colleagues familiar with the content. Reliability was determined by reviews and piloting by a panel of psychometricians. A Likert-type scale was used to provide variance.

Graduate assistants administered the questionnaire as an anonymous survey to 84 students enrolled in several sections of science methods classes at a small, rural university in a Mid-Eastern section of Appalachia. The survey was delivered as a pretest at the beginning of the semester and a posttest at the end of a semester. The final results were analyzed using a paired-t test.

Results

Upon examination of the data, certain important findings were revealed. Taking into account the pretest and posttest science achievement scores, the percent correct increased from the pretest data as compared to the posttest data. Please refer to Figure 1. It is important to note that 38 student surveys related only to achievement were removed from the data pool due to possible contamination from another survey the students were given during the same semester.

Figure 1

	Pretest	Posttest
transfer of energy	51.3	82.4
potential energy	53.8	100.0
monomers	5.1	29.4
magnet	10.3	76.5
electron	5.1	85.3

Taking into account the 12 ecosystem questions related to instruction, learning environment, teaching ability, and the ten science self-efficacy questions, there were significant changes between the pretest and posttest data. The preservice teachers felt they could facilitate learning for students of diverse backgrounds [$t(68)=7.41<.01$], engage in ongoing assessment and use multiple methods of assessment

[t(68)=10.38<.01], and design/manage the learning environment [t(68)=9.88<.01]. The students also felt they could develop communities of cooperative/collaborative learners that encourage student independence [t(67)=10.43<.01]. The science methods students believe they could use lower and higher levels of divergent thinking [t(68)=9.20<.01], use group-centered activities [t(68)=7.95<.01], and integrate activity results from theories of other disciplines to increase learning [t(68)=10.51<.01]. The students also believed they were competent to collect data as the primary source of student/teacher interactions [t(68)=10.36<.01] and use observations to generate discussions about the activities [t(68)=9.51<.01].

The survey results also indicated that the students felt confident to design and implement developmentally appropriate Life Science lessons [t(68)=11.00<.01], Earth Science lessons [t(68)=11.65<.01], Astronomy lessons [t(68)=9.60<.01], and Physics lessons [t(68)=8.97<.01]. The future teachers believe they could design and implement a constructivist type lesson for all students [t(68)=11.36<.01], confident they could teach hands-on science in cooperative learning groups [t(68)=9.82<.01], and motivate students to enjoy science [t(68)=8.28<.01]. To further take self-efficacy into account the preservice teachers felt confident they could answer questions about science experiments [t(68)=9.54<.01] and felt competent in their science achievements [t(68)=10.17<.01]. Gender differences were not present within the study given the fact that there were a limited number of male respondents.

Discussion

The results of this study are encouraging and clearly indicate the importance of methods classes in preparing teachers of the future. Based on current research, the idea

of constructivism as a theory of learning and thinking in combination with the criteria that influence self-efficacy hold much promise for teaching.

After repeated practice in the construction of knowledge about content and pedagogy, the study results indicate that preservice teachers have a higher degree of self-efficacy, felt more confident about planning lessons and activities for students to facilitate learning, and provide effective teaching to their classrooms. There were significance in their perceived ability to create developmentally appropriate lessons in Life Science, Earth Science, Astronomy, and Physical Science. This is extremely significant considering the fact that over 83% of these students, on an informal, non-scientific survey, had only taken Biology as their two required science courses. The preservice students also felt confident that they could be effective in culturally diverse classrooms. Motivating students was another area that showed significant correlation between pre and post testing. The key to effective teaching is being able to motivate students and provide a challenging and comfortable learning environment. The results indicate that the preservice students felt that they could be successful in that task.

One of the latest buzzwords in education today is "multiple assessment." The students now feel confident in creating and delivering multiple assessments. This logically follows the significance shown in being able to create activities that encourage divergent and critical thinking.

The preservice students show a confidence in building social skills. There is significance in the area of cooperative and collaborative learning groups and in being able to generate discussions based on observations. According to Felsen (1984), the use

of cooperative/collaborative groups is one of the best instructional strategies to boost self-efficacy.

In summary, a constructivist-learning situation shows great promise in training preservice teachers. The preservice teacher will be armed with the skills and tools to make learning individualized and yet a cooperative endeavor that will produce brighter kids with brighter futures.

Conclusion

One of the National Education Goals is to make American children first in the world in science and math. First published more than a decade ago, the results of the National Assessment of Educational Progress (NAEP) tests find that America is still far behind other emergent countries. Considering so many reform efforts underway since the mid 1950's, there should be answers abounding. Instead, all the education community hears are stories of doom and gloom. There are more questions than answers and no one is willing to take responsibility.

This research study examines the age-old saying, "teachers teach as they were taught." It is the contention of these researchers that one must model correct teaching methods and interactions within the training classes of the preservice teachers to affect change. If a teaching method is urged in the public schools, the colleges are doing a disservice to the teachers it prepares if they are not taught the correct theories and postulates.

This research demonstrates empirically that teachers in training respond well to constructivism, collaborative and cooperative group work, mentoring, reflection, hands-on science, and inquiry-based science and math. Integrated math and science courses are

bridges to understanding and success in other fields of study. Also, these components are vital in enhancing self-efficacy and problem solving. Self-efficacy is perhaps the key to developing effective teachers. By following practices that include strategies to actively involve all students and that remove any cultural and/or ethnical impediments, children can and will learn. The teacher must be ultra-sensitive to the environment of the classroom and be willing to guide and facilitate learning experiences that promote social skills, critical thinking skills, problem solving strategies, and instill life-long learning experiences. A primary goal of American education has always been to prepare students to be successful in the careers of the future. This can be the impact of a good classroom environment where students build and retain knowledge of "how to do" rather than just assimilating facts.

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