(1) Dept of Educ. - FIPSE 10/91

THE COMPREHENSIVE PROGRAM
FUND FOR THE IMPROVEMENT OF POSTSECONDARY EDUCATION

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Preliminary XX Final ____

This application should be sent to:
No. 84.116A
U.S. Department of Education
Application Control Center
Room 3633
Washington, D.C. 20202-4725

1. Application No.

2. Employer Identification No.

3. Project Director
(Name and Complete Mailing Address)

Joe Andrade
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Area Code and Number

4. Institutional Information
Highest Degree Level
____ Two Year
____ Four Year
____ Graduate
XX Doctorate
____ Non-Degree Granting
Other: ____

XX Public
____ Private

5. Federal Funds Requested:

1st Year Only	$65,371
2nd Year (If Applicable)	$98,148
3rd Year (If Applicable)	$96,263
Total Amount:	$260,382

6. Duration of Project:
Starting Date 9/92
Ending Date 8/95
Total No. of Months 36

7. Proposal Title: Utilizing Conceptually Based Science Instruction to Improve the Content Understandings of Elementary Teacher Candidates

8. Brief Abstract of Proposal: (Do not leave this blank)

In this project a team of faculty from the Colleges of Science and Education will develop, field test and evaluate a sequence of courses in science content for prospective elementary teachers. The main purpose of the proposed new program is to change the way the science content classes are taught at the university level. Teacher candidates who learn science concepts in traditional undergraduate courses which utilize lecture and demonstration methods tend to retain naive conceptions and misconceptions. They enter teacher education, therefore, seriously deficient in their understanding of the science content they will teach to children. This project is designed to significantly strengthen the subject matter understandings of elementary school teachers. Science concepts will be taught through the conceptually-based instructional methods developed by recent research in cognitive psychology. It is anticipated that the findings of this project will have wide implications for the pedagogy used in undergraduate education in the College of Science.

9. Legal Applicant
(Name and Complete Mailing Address)

University of Utah
Salt Lake City, UT 84112

10. Population Directly Benefiting From The Project

300 Undergraduate Teacher Education Majors
(and subsequently 100/year)
Congressional District(s)

11. Certification By Authorizing Official

The applicant certifies to the best of his/her knowledge and belief that the data in this application are true and correct and that the filing of the application has been duly authorized by the governing body of the applicant and the applicant will comply with the attached assurances if the assistance is approved.

Dr. Cliff Drew — Associate Dean for Research (801) 581-8221
Name — Title — Phone

Utilizing conceptually based science instruction to improve the content understanding of elementary teacher candidates

Statement of the problem

Throughout the past thirty years a series of curriculum reform movements have attempted to upgrade the teaching and learning of science in the public schools (Smith, 1979). These reforms often emphasized the development of "hands on" inquiry oriented instruction designed to promote students' conceptual knowledge by building on prior understandings, active engagement with the subject matter content and application to real world situations (see for example, Driver, 1983; Karplus & Thier, 1967; Smith & Anderson, 1984; Zacharias & White, 1979). However, these reforms have been largely unsuccessful. Science instruction remains primarily didactic, dominated by lecture, demonstration, textbook readings and memorization (Biddulph, 1982; Renner, Abraham, Gryzowski & Marek, 1990). This traditional approach to instruction has been consistently shown to be ineffective in engaging student interest or developing conceptual understanding of the subject matter (Anderson & Smith, 1987; Driver, 1983; Hewson & Hewson, 1988).

Part of the problem is that these reform efforts have tended to focus on student rather than teacher learning. It is typically assumed that teachers, if provided with innovative curricula and shown how to use them, will be able to effectively implement them in their classrooms (Shulman, 1986). This is not the case. To teach conceptually, an instructor needs to understand the content conceptually. There is increasing evidence, however, that many teachers are seriously deficient in their understanding of the subject matter they teach (Ameh & Gunstone, 1988; Ball, 1988; Neale & Smith, 1989; Smith, 1987). This is not surprising given that most teachers learned their mathematics and science content, in grade schools and college, through the same ineffective traditional methods reformers are seeking to replace. They tend to teach as they were taught and expect students to learn as they learned (Ball, 1988; Lortie, 1975; McDiarmid, Ball & Anderson, 1988). Breaking this didactic teaching-learning-teaching cycle will require an increased focus on teachers as learners and on pedagogy at the university level.

This project will develop and field test a sequence of courses in science content for elementary teacher candidates. It will utilize the combined expertise of faculty in the Colleges of Science and Education to develop a two quarter sequence of courses covering core biological and physical science concepts. The courses will emphasize the use of conceptually-based pedagogy.

The current program

In the current University of Utah teacher education program elementary education majors are required to complete an undergraduate biology class as part of the Liberal Education requirements and two elective science classes to fill State credentialing requirements. A survey of elementary education candidates' transcripts indicates that the most frequently selected science classes are Trees and Shrubs and Common Medicines (Stofflet, 1991). These classes do not cover many of the core concepts in the elementary school science curriculum. In particular, the content is deficient in physical science concepts as well as the broad over-arching concepts critical to an adequate understanding of biology. These courses are also taught didactically through lecture and demonstration.

Research on teacher candidates who have taken these courses indicates they retain naive conceptions and misconception about the science content. The teacher candidates were given a 12 question paper and pencil assessment about the water cycle and related weather phenomena (see Table One). The topic of the weather cycle was chosen because of its prevalence at all levels of the elementary school curricula. The assessment demonstrated that the majority of the teacher candidates entered the teacher education program with poor understanding of science content. In ten of the 12 questions, the conceptions of between 60-90% of candidates were naive or scientifically naive. These prospective teachers' understanding of the science content was similar to elementary school-age students they would be teaching. It is clear that the prerequisite courses taken by the teacher candidates were insufficient at addressing and developing adequate scientific conceptions necessary for effective elementary school teaching. It is obvious that a new approach to science instruction at the college level is required.

The new program: a conceptual change approach to undergraduate science education

The main purpose of the proposed new program is to change the way the science content classes are taught at the university level. Science concepts will be taught through the conceptually-based instructional methods developed by recent research in cognitive psychology. The specific focus of this project will be on the development, implementation, evaluation and dissemination of prerequisite science content courses for prospective elementary school teachers. It is hoped, however, that the findings of this project will have wide implications for general the pedagogy used in undergraduate education in the College of Science.

Cognitive approaches to science education hold that learners' understanding of subject matter is a product of what they are taught and what they bring to any instructional situation. This view is based on increasing evidence from cognitive science research that individuals' prior knowledge and beliefs powerfully affect the ways in which they make sense of new ideas (see, for example, Anderson, 1984; diSessa, 1982; Posner, Strike, Hewson, & Gertzog, 1983; Schoenfeld, 1983). Students enter classrooms with many preconceptions about the content they study: these preconceptions are highly resistant to change and can interfere with the learning of scientifically accepted theories (Anderson & Smith, 1987; Driver, 1983; diSessa, 1982; McCloskey, 1983). The findings of this research indicate that the development of scientific understanding involves a process of 'conceptual change' in which naive preconceptions need to be identified, disconfirmed and restructured in order for scientifically validated theories to be accepted (Posner, Strike, Hewson, & Gertzog, 1983).

This theoretical perspective has been especially influential in science education research circles where a series of studies have investigated children's naive conceptions and conceptual changes approaches to science instruction (see for example, Driver, 1983; diSessa, 1982; McCloskey 1983; Posner, Strike, Hewson & Gertzog, 1983; Roth, 1984). To date, however, little attention has been paid to the development of teachers' understandings of science. This project proposes to develop university courses which use conceptual changes approaches as a part

of the science instruction provided for prospective elementary school teachers.

Evidence of the effectiveness of these instructional approaches can be found at the university level. Champagne, Gunstone and Klopfer (1985) found that in a traditionally taught undergraduate physics class advanced students persisted in believing that constant motion requires constant force despite the numerous examples to the contrary presented in the text and lectures. However, when the instructors subsequently developed representations of motion, velocity and acceleration that elicited and directly addressed students naive conceptions, students developed more scientifically accurate conceptions. Neale and Smith (1989) report similar findings with a group of experienced teachers. They found that teachers went through the same conceptual change processes as students when developing accurate scientific conceptions.

A pilot study at the University of Utah: An experimental three week conceptually-based science content unit was developed and field tested with a group of elementary teacher candidates (Stofflet & Stoddart, 1991). The content was taught using a five step conceptual change science teaching method developed from the work based on students' conceptual change (Driver, 1983; Driver, Guesne & Tiberghien, 1985; Hewson & Hewson, 1988; Posner, Strike, Hewson & Gertzog, 1982). The method involves (1) eliciting students preconceptions, (2) guided exploration of phenomena including disconfirming experiences, (3) questioning and discussion to lead students to scientifically accepted explanations, (4) comparing new conceptions to original preconceptions to create disequilibrium, and (5) applying new concepts to real world situations. Table Two elaborates on this method. On entry to the class, 49% of the 26 novice teachers' conceptions were naive, 36% scientifically naive, and only 15% demonstrated scientific understanding. These teacher candidates had limited understanding of the content they were preparing to teach. After three weeks of content instruction using conceptual change methods, however, the candidates' scientific understandings of the water cycle had improved significantly. Seventy percent of students' responses on the post-test were scientifically accurate.

A science content sequence for elementary school teachers: In the proposed project, a team of faculty from the Colleges of Education and Science will develop a sequence of two science content classes for prospective elementary school teachers. The courses will focus on core concepts in biological and physical science which are taught in the elementary school curriculum and will be taught using conceptual change pedagogy. Two faculty members from the College of Science: Dr. Joe Andrade (Bioengineering) and Dr. Sid Rudolph (Physics), and two from Education: Dr. Julie Gess-Newsome (Science Education) and Dr. Trish Stoddart (Teacher Education) will work together to develop, co-teach and evaluate the new courses.

Timeline and project activities

Year one:

(i) Identification of core science concepts through an analysis of national and state curriculum frameworks.

(ii) Review of literature on students' conceptions and misconceptions about the core science concepts.

(iii) Survey of a random sample of University of Utah undergraduate students' and prospective teachers' conceptions about the core science concepts.

(iv) Development of curriculum materials and course activities based on science concepts, student preconceptions and the conceptual change model.

Year two:

(i) Field testing of courses which include the core biological and physical science concepts identified in year one. These courses will be team taught by one faculty member from each of the Colleges of Science and Education.

(ii) Analysis of pre and post assessment of student conceptions. Comparison with a random sample of undergraduate students who have completed traditionally taught science courses which address similar concepts.

(iii) Revision of courses.

Year three:

(i) Team teach revised courses and assess student conceptions.

(ii) Develop and disseminate curriculum units.

Table One

Percentage of teacher candidates in four categories of science content understanding

		N	SN	PU	SU
1.	Often when a glass of ice water sits out for awhile, a mist-like substance forms on the outside of the glass. What is the substance?	27	9	0	64
2.	Where did the substance in #1 come from?	36	23	9	32
3.	How did the substance in #1 form?	36	36	5	23
4.	A pot of water is on the stove. Several minutes later bubbles form on the bottom of the pan. What substance is in the bubbles?	50	41	0	9
5.	How did the bubbles in #4 form?	31	59	5	5
6.	You place a plate over the pot in question #4 and it gets a mist-like substance on it. What is this substance?	23	14	18	45
7.	Where did the substance in #6 come from?	59	18	0	23
8.	How did the substance in #6 form?	54	23	14	9
9.	How do clouds form?	36	32	27	5
10.	What causes rain?	50	32	9	9
11.	How does snow form?	73	23	0	4
12.	How does fog form?	64	9	18	9

Abbreviations: N = Naive SN = Scientifically Naive
PU = Partial Understanding SU = Scientific Understanding

Table Two

The Conceptual Change Teaching Model

Step One: Diagnosing preconceptions.
Students are given opportunities to voice their ideas about science phenomena. It is important that both the ideas and reasons the students believe the ideas be clarified. This step is usually done through a series of written exercises and discussions, which relate to visual examples of the phenomena in question (such as demonstrations, slides, nature walks etc.). This allows the teacher to determine the starting point and focus of the instruction and activities.

Step Two: Exploring the phenomena in question.
Students are given opportunities to explore phenomena using guided discovery methods. The teachers provide materials and focusing questions that allow students to observe the phenomena in question, especially using experiences that will provide counter examples to students naive theories and illustrate the particular concepts in a clear fashion.

Step Three: Lead students to scientifically accepted explanations.
Students discuss the results of their experiments from step two with their teacher and classmates. The teacher uses Socratic questioning to lead students to the scientifically accepted explanations. When students have agreed with the accepted explanation, they are asked to restate the concepts in their own words. It is at this point that new vocabulary is introduced, if applicable.

Step Four: Disequilibrium.
Students are asked to compare their new ideas stated in step three with their original ideas stated in step one. The teacher asks whether each idea presented in the first step is correct. Students state in their own words whether they still believe the original ideas, and explain why. If students have still retained their misconceptions, the teacher moves back to step two or three to provide counter experiences. When students are able to distinguish between scientifically accepted ideas and naive theories, they are ready to move on to the final step.

Step Five: Applying new concepts to real world explanations.
Children frequently are unable to connect what they learn in science class to the outside world. This step is designed to facilitate this transfer. The teacher asks the students to provide examples of the phenomena occurring in their own lives. The students then explain how the concept works for each situation. If the students are unable to come up with the examples on their own, the teacher may provide them.

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