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ABSTRACT

As part of an investigation of the influence of a 3-week institute upon secondary biology and earth science teachers regarding their self-confidence with respect to the teaching of evolutionary principles, 19 inservice teachers participated in discussions of content presentations and instructional activities. The following research questions were proposed: (1) To what extent can a 3-week institute influence teachers' understanding of the nature of science, acceptance of the theory of evolution, and understanding of applied evolutionary principles? (measured by the Nature of Science Scale); (2) Can a 3-week institute reduce teachers' self-perceived anxieties regarding the teaching of evolution? (assessed by the State-Trait Anxiety Inventory); and (3) What concerns might teachers have regarding the potential use of a student-centered peer discussion as an instructional strategy to teach evolution? (measured by the Stages of Concern Instrument). At the conclusion of the institute, which was sponsored by the National Science Foundation, participants showed significant increases in acceptance of the theory of evolution and content understanding of evolution, as well as significant reduction in anxiety. Moderate to strong consideration of peer discussion technique was also apparent. (23 references) (KR)

TEACHING EVOLUTION: UNDERSTANDING, CONCERNS,
AND INSTRUCTIONAL APPROACHES

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TEACHING EVOLUTION: UNDERSTANDING, CONCERNS, AND INSTRUCTIONAL APPROACHES

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ABSTRACT

The investigators sought to examine the influence of a three-week institute upon secondary biology and earth science teachers regarding their self-confidence with respect to the teaching of evolutionary principles. The institute, funded by the National Science Foundation, was designed to promote the philosophical and applied nature of science, provide enhanced content, and provide a forum for teachers to discuss common problems associated with the teaching of evolution. In concert with the instructional conduct of the institute, the following research questions were proposed: 1) To what extent can a three-week institute influence teachers': (a) understanding of the nature of science; (b) acceptance of the theory of evolution; or (c) understanding of applied evolutionary principles?; 2) Can a three-week institute reduce teachers' self-perceived anxieties regarding the teaching of evolution? and ... 3) What concerns might teachers have regarding the potential use of a student-centered, peer discussion as an instructional strategy to teach evolution?

The nineteen institute participants were required to actively engage, both formally and informally, in discussions related to both content presentations on both biological and geological themes and a variety of instructional activities designed, taught, and modelled as teaching methods by the principal investigators. The scope of these activities ranged from field trips to both ecological and fossil sites, to traditional lectures, question/answer, small group issues discussions, and other creative inquiry-based methods of instruction. The final week was used to provide participants an opportunity to research and design (days 11 and 12) an activity for eventual presentation to fellow participants (days 13 - 15).

At the conclusion of the institute, participants showed significant increases in their acceptance of the theory of evolution ($Z = 2.93$; $p < 0.01$), content understanding of evolution ($Z = 2.72$; $p < 0.01$), and an applied understanding of the nature of science ($Z = 2.74$; $p < 0.01$). In addition, participants experienced a significant reduction in their anxiety ($Z = 3.51$; $p < 0.001$) regarding the teaching of evolution in the secondary science classroom. Finally, a qualitative examination of the participants' Stages of Concern (SoC) composite profiles for normative "pretest" and "posttest" percentile data, indicated a shift away from the three lower (Awareness -- Stage 0; Informational -- Stage 1; and Personal -- Stage 2) and toward the three higher (Consequence -- Stage 4; Collaboration -- Stage 5; and Refocusing -- Stage 6) Stages of Concern. In addition, the relative shifts occur in a direction that favors a moderate to strong consideration for the use of a peer discussion instructional format for the teaching of evolution.

INTRODUCTION & PURPOSE

Many science teachers have experienced frustration, challenges, and even outright criticism when the study of evolution is presented as an instructional unit in the secondary classroom. The issue can certainly be a sensitive one and the potential confrontation it engenders is very real. This can be especially true if students exhibit a high degree of anxiety with respect to ambiguity and as a consequence, may perceive the topic of evolution to be in conflict with their own beliefs. Individuals with a higher anxiety regarding ambiguity often exhibit a tendency towards dualism as a world view. Dualistic perceptions have been described by Perry (1970) as viewing an issue from a discrete "right-wrong" rather than a more generalized or global "better-worse" perspective. How then do science teachers provide an appropriate context for students to deal with their own acceptance of ambiguity, and hopefully as a consequence, to understand the nature of science and premises of evolutionary theory?

One response to this problem is simply to ignore it, not directly teach evolution, and thereby avoid the consequences of potential confrontation (Eglin, 1983; Johnson, 1985; McCormack, 1982; Nelkin, 1982). This approach is, of course, unsatisfactory, since it also avoids real intellectual challenges for students (Scharmann, 1990). Another response is to more adequately and honestly address the problem through diversified instructional strategies (Nelson, 1986; Scharmann, 1990) that possess a greater recognition for the central instructional role of scientific theories (Duschl, 1988; Hodson, 1988; Duschl, 1990). The success of the latter alternative, however, presupposes that secondary science teachers possess an adequate understanding of the nature of science and are comfortable themselves with the theory of evolution. Recent evidence (Eve & Dunn, 1990; Johnson & Peeples, 1987; Nelson, 1986) would suggest that neither of these presuppositions necessarily possesses adequate validity.

Thus, in order to facilitate a consideration of alternative instructional strategies and provide a forum for the discussion of common problems related to the teaching of evolution, a three-week summer institute, sponsored by the National Science Foundation (NSF), was proposed and subsequently funded for the purposes of:

1. Updating participants' background in the nature of science and knowledge of biological and geological science content related to evolutionary theory;
2. Enhancing participants' abilities to assess and address student misconceptions regarding scientific concepts that contribute to historical and contemporary views of evolutionary theory; and
3. Assisting participants in the development of units of study and daily lessons that integrate the nature of science, updated science content, and alternative instructional strategies for teaching evolution.

Research Agenda

To evaluate institute activities, the principal investigators sought to collect data from practicing secondary science teachers that would provide a partial evidence base to address the following research questions:

1. To what extent can a three-week institute influence teachers': (a) understanding of the nature of science; (b) acceptance of the theory of evolution; and/or (c) understanding of applied evolutionary principles?
2. Can a three-week institute reduce teachers' self-perceived anxieties regarding the teaching of evolution? and ...
3. At what stage of concern might teachers be regarding the potential use of a student-centered, peer discussion as an instructional strategy to teach evolution?

DESIGN AND PROCEDURES

Institute participants were selected consistent with a set of eligibility criteria mutually agreed to by the principal investigators and the NSF. Among these criteria were the possession of secondary teacher certification in either biology or earth science, a degree in science education, a minimum of two years of teaching experience, and a letter of direct support for attendance from a district administrator. Highest priority was reserved for applicants demonstrating a rural instructional assignment; one in which the applicant was required to provide the primary instruction for both the biological and earth sciences. Although the participating teachers were selected from an applicant pool not necessarily representative of the "average" biology or earth science teacher, the final participant group, numbering nineteen secondary science teachers, constituted neither an "elite" nor an "under-prepared" sample. Among these nineteen participants were 12 males, 7 females. Six of nineteen teachers reported an instructional assignment to be exclusively biology, two exclusively claimed earth science, while eleven reported an instructional role requiring them to teach both biology and earth/general science. An examination of all personal data variables such as age, total years of teaching experience, years of science teaching experience, gender, academic degree held, etc., revealed no significant correlations with either each other or pertinent data collected for the purpose of evaluating the effectiveness of the institute experiences.

The three weeks (15 days, 6 hours/day) of the institute were conducted in two phases. During the first two weeks, participants were explicitly required to actively engage, both formally and informally, in discussions related to direct content information presented on both biological and geological themes. They were also to engage in discussions regarding the uses for the various instructional activities designed, taught, and modelled as teaching methods by the principal investigators. The scope of these explicit activities ranged from field trips to both ecological and fossil sites, to traditional lectures, question-and-answer, small group "issues" discussions, and other more inquiry-based methods of instruction.

Implicit, however, throughout the first two weeks were two additional themes that pervaded each formal instructional session. The first of these concerned directing the participants away from the use of direct "teacher-centered" and towards the use of more indirect "student-centered" instructional approaches. Indeed, during the first two days of the institute, one participant voiced a common frustration that ... "no matter how I seem to approach the topic of evolution, it just makes matters worse". Scharmann (1990) alluded to this exacerbation of the issue as being directly attributable to the dualistic nature of the learner coupled with too "teacher-centered" an approach to do anything other than maintain and strengthen the students' polarized dualism.

Thus, throughout the first week, readings in natural history [i.e., S.J. Gould (1983), Hen's Teeth and Horse's Toes, New York: W.W. Norton & Company] were supplied and suggested as supplements; inquiry-based investigations were performed and suggested as complements to regular classroom activities. Although participants enjoyed the readings and activities, they still voiced the shared futility that ... "I've tried many of these approaches and my students are fine with them until I try to tie it in more directly with the 'E' word" (as many participants alluded to how carefully they must use the word in their school districts). This latter problem may stem from the fact that these kinds of activities permit students to remain detached from confronting their own dualism with respect to the issue of evolution. Thus, Scharmann (1990) and Nelson (1986) have promoted the use of small group, student-centered "peer" discussions as a means to generate disequilibrium among students without making the teacher the focal point of the controversy. Students possessing a strong and well established rapport with an instructor will, according to Scharmann (1990), generate a sufficient level of conflict among themselves and eventually turn to the 'trusted' teacher to assist them in resolving the conflict; conflict that arose among peer students in the small group "peer" discussions and not from the teacher's direct instruction. Thus, dualism can be confronted while providing students with a place to stand between two extremes. This 'place-to-stand' is especially critical if we are to promote a more adequate understanding of the nature of science and why it is that scientists feel that the theory of evolution is such a major unifying theme for study in the biological sciences. The use of "peer" discussion as an alternative instructional approach became a focus mid-way through the second week of the institute. It is more fully explicated by Scharmann (1990).

The second implicit theme pervasive during the first two weeks concerned a more contemporary portrayal of the nature of science. Kimball (1967) contended that once an individual has graduated from undergraduate studies, little change can be expected with respect to their philosophic understanding of the nature of science. Others, however, contend that changes in an understanding of the nature of science can be fostered through a more indirect and applied context for the philosophic tenets of science (Duschl, 1990; Kitcher, 1982; Laudan, 1977; Nelson, 1986). The investigators accepted the latter view and adopted a means to discern such potential changes. A summary of the eclectic view promoted by the investigators for the nature of science is reported in the following:

> Theories, like everything else in science, have a developmental history. All theoretical explanations that attempt to generalize across data sets and explain lawlike empirical relationships have a beginning. It is absurd to think that only useful ideas have ever been proposed in science. The past is no different than the present in this respect. Certain explanations come to have scientific merit .... The task that faces students [and teachers] of science is how to distinguish the crank ideas from the truly scientific.
>
> (Duschl, R.A., 1990, p. 56)

The final week was used to provide participants with opportunities to synthesize institute activities, and to research and design (days 11 and 12) an activity for eventual presentation to fellow participants (days 13 - 15).

Data Collection and Instrumentation

Data were collected both prior to the first day's and immediately following the last day's institute presentations and activities. The data collection instruments were matched wherever possible to the research questions of interest posed by the principal investigators.

Research Question 1: The Nature of Science and Acceptance of Evolution

An assessment of participants' understanding of the nature of science was estimated in two contexts: philosophical and applied. An assessment of a philosophical understanding of the nature of science was measured by the 29-item statement, 3-point (Agree, Uncertain, Disagree) Likert-type "Nature of Science Scale" (NOSS) developed by Kimball (1967). The NOSS measures a fairly stable construct that is less subject to the influence of specific educational experiences. Evidence for the reliability of the NOSS was reported by Kimball (1967); the instrument possesses a split-half reliability correlation coefficient of 0.72. Evidence for the construct validity of the NOSS was determined by comparing the responses made by groups known to differ in their orientations toward science. In establishing this discriminant validity, Kimball (1967) was able to provide evidence that the NOSS successfully discriminated among groups according to their progressive understanding of the nature of science.

In addition, in contrast to the NOSS, to provide a measure of participants' applied understanding of the nature of science (more subject to being influenced) and direct acceptance of the theory of evolution, a 25-item statement, 5-point (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree) Likert-type untitled instrument developed by Johnson and Peeples (1987) was administered; 20 statements assess an understanding of the nature of science in an applied context and an additional 5 statements directly measure a respondent's acceptance of evolution and evolutionary theory. Johnson and Peeples (1987) reported internal consistency reliabilities of 0.78 and 0.77 for two respective sections of the questionnaire, taken from a population sample of 1,812 undergraduate students from 34 participating higher education institutions. Validity was established by means of the known group differences technique. The developers reported that the instrument discriminated an acceptance of evolution as a function of a progressive understanding of science. Finally, to provide a basis for examining an understanding of applied evolutionary principles (biological content), an additional 10 item statements, written by one of the principal investigators, were added to the Johnson & Peeples questionnaire using a similar Likert scale format.

Research Question 2: Anxiety about Teaching Evolution

Anxiety about teaching evolution was assessed through the use of the "State-Trait Anxiety Inventory" (STAI). The STAI, was initially developed by Spielberger, Gorsuch, and Lushene (1970); however, a revised form of the STAI (Spielberger, 1983) was used in this present research effort. The STAI possesses two subscales, S- and T-anxiety. S-anxiety measures anxiety about a specific situation (i.e., teaching evolution) and is subject to being influenced by training and/or educational experiences. T-anxiety is a more stable measure of individual differences, in proneness to anxiety, and is less subject to educational influences. The specificity of the this measure to science education has been repeatedly demonstrated (Sherwood & Westerback, 1983; Westerback & Primavera, 1988; Westerback & Long, 1990).

Research Question 3: The Use of "Peer" Discussion Instruction

Finally, to assess participants' understanding of and concern for the use of novel instructional approaches for the teaching of evolution, the well known "Stages of Concern (SoC)" instrument (Hall, George, & Rutherford, 1979) based on the Concerns-Based-Adoption-Model (CBAM) for introducing innovations was administered. The SoC measure is a questionnaire consisting of 35 item statements which reflect a respondent's understanding of, concern with, or attitude about a new program, instructional approach, or specified innovation. A respondent is required to circle a number from 0 to 7. A "0" reflects that a given statement is presently "irrelevant" as a concern; a "3" is indicative of a statement being "somewhat true of me now," and a "6" illustrates a "very true of me now" concern by the respondent for a given statement. The 35-items are subdivided into seven subscales; each subscale is represented by five item statements from the original 35. Each subscale is subsequently comprised by a standardized percentile for each subscale. The subscales ultimately represent a continuum of "Stages of Concern" from unfamiliarity with to great familiarity with a specified innovation. These stages, in ascending order of familiarity/use are: Awareness, Informational, Personal, Management, Consequence, Collaboration, and Refocusing. The developers of the SoC have accumulated an impressive array of reliability and validity data (James, 1991).

The initial SoC is generic in form so that it might be used to determine concerns about a wide variety of innovations or approaches. In this research effort, the specific innovation under consideration, to be measured by the SoC, was a peer-discussion instructional format. Peer discussions have been delineated by Scharmann (1990) and Nelson (1986) as being particularly effective approaches with respect to the teaching of evolution.

RESULTS & DISCUSSION

The procedures used to identify and ultimately select participants, upon which data were collected and subsequently analyzed, precluded the use of traditional parametric analyses for several reasons. First, the selection criteria, while placing a priority on neither an elite nor under-prepared participant group, actually guaranteed a non-random participant group. Second, since it was a non-random group, an appropriate (or comparable) control group was not available. Finally, the number of participants (19) was relatively small; too small upon which to conduct a more liberal analysis with confidence. Therefore, a more conservative analysis was adopted using the Wilcoxon test, a nonparametric "repeated measures" analog for the traditional repeated measures "t-Test" (Conover, 1980). The Wilcoxon test is a signed-ranks procedure. It generates a test statistic which compares the pretest with posttest median and computes a standard z-score for the difference in the magnitudes of the medians from each time-frame of collected data. The results to follow are reported by individual research question.

Research Question 1: The Nature of Science and Acceptance of Evolution

At the conclusion of the 3-week institute, participant posttest scores indicated a significant increase in their applied understanding of the nature of science ($Z = 2.74$; $p < 0.01$); however, participants did not show any significant difference with respect to their philosophical understanding of the nature of science. The latter finding is consistent with results reported by Kimball (1967) for post-baccalaureate science teachers and practicing scientists in the sense that this philosophical understanding does not change for individuals beyond the undergraduate years of study. Therefore, NOSS scores were used as a cross-check regarding the influence of other measures of the nature of science; thus, in this research effort, it lends credence to the validity of the significant finding for an understanding of the applied nature of science.

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INSERT TABLE 1 about here

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Finally, concerning research question 1, participants showed a significant increase in their overall acceptance of the theory of evolution ($Z = 2.93$; $p < 0.01$) and improved upon their general content understanding of evolutionary principles ($Z = 2.72$; $p < 0.01$).

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INSERT TABLES 2 & 3 about here

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Research Question 2: Anxiety about Teaching Evolution

A set of comparison results was obtained for the two measures of State vs. Trait anxiety. These results were strikingly similar to those obtained for the philosophical versus applied contexts regarding an understanding of the nature of science. At the conclusion of the three-week institute, participant anxiety (S-anxiety) regarding the teaching of evolution in secondary science classrooms was highly and significantly reduced ($Z = -3.51$; $p < 0.001$). By contrast, Trait-anxiety which was used to provide a cross-check of measurement stability, was not reduced by any significant quantity. This result, according to Spielberger (1980)

Westerback and Long (1990), indicates the confidence one can have in the validity of the reduced S-anxiety.

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INSERT TABLE 4 about here

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Research Question 3: The Use of "Peer" Discussion Instruction

Finally, a qualitative examination of the participants' Stages of Concern (SoC) composite profiles for normative "pretest" and "posttest" percentile data, indicated a shift away from the three lower (Awareness -- Stage 0; Informational -- Stage 1; and Personal -- Stage 2) and toward the three higher (Consequence -- Stage 4; Collaboration -- Stage 5; and Refocusing -- Stage 6) Stages of Concern. In addition, the relative shifts occur in a direction that favors a moderate consideration for the use of a peer discussion instructional format for the teaching of evolution and a potential willingness among participants to share or collaborate with other secondary science teachers. The remaining Stage of Concern, Management (Stage 3) did not shift and represented a "breakpoint" in the overall composite profile shifts. Caution must be exercised, however, in the interpretation of SoC results. The SoC is intended to measure more long-term adoption behaviors. The present data collected seem to indicate, on a more pragmatic level, that the participants at the conclusion of the institute had a better idea what the investigators meant by a "peer discussion" instructional format. The relatively flat line, however, could also be interpreted to mean that participants were convinced that the instructional approach works well for the investigators ... but, they were not sure that it would indeed work well for themselves. [Follow-up data for a small group of institute participants, those returning as mentor teachers for the second year institute were not available at the time of this writing.]

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INSERT FIGURE 1 about here

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CONCLUSIONS

In the absence of a true comparison or control group, it is often difficult to make accurate generalizations; however, the investigators' intent in this report was to describe the evaluation of a NSF-sponsored project and not portend to claim a true experimental design. Three research questions were posed for which relevant data was collected and analyzed. The results, obtained in this investigation, indicate that it is possible to increase participant teachers' applied understanding of the nature of science, overall acceptance of the theory of evolution, and content knowledge in applied evolutionary principles. Perhaps more importantly, this study indicated a strong potential to reduce anxiety regarding the teaching of evolution in the secondary science classroom.

There is little doubt that the formal activities of this institute certainly contributed to the significant findings of this study. However, the informal and anecdotal influences of peer teachers in sharing, arguing, and coming to consensus with one another on a variety of issues and topics raised throughout the three-week experiences may have been as powerful as the formal activities themselves. This statement is amplified by the rural teaching assignment of most of the institute participants. Teachers in rural districts, when confronted with challenges regarding curriculum and instruction considerations, especially confrontational issues, do not have the luxury of being able to conveniently discuss the issue with a science teacher peer. Thus, the written assessment, by participant teachers, regarding the overall effectiveness of the institute experiences underscores their relief in sharing common instructional concerns regarding the nature of science and understanding of evolutionary principles.

The institute directors, upon the examination of the empirical data, reading participant written assessments, and discussion of anecdotal experiences over the three weeks of the institute conclude that secondary science teachers need ...

1. Peer reinforcement regarding their efforts in accurately portraying the nature of science;
2. Peer reinforcement regarding their efforts in accurately portraying a variety of principles associated with evolutionary theory;
3. To assess and correct student errors and misconceptions regarding theories in general and evolution in specific; and
4. To move away from exclusively teacher-centered and towards student-centered & interactive instructional strategies, involving the history and philosophy of science with respect to the teaching of evolution.

TABLE 1. UNDERSTANDING OF THE NATURE OF SCIENCE -- APPLIED VERSUS PHILOSOPHICAL CONTEXTS

APPLIED CONTEXT	MEASURES	PRETEST N = 19	POSTTEST N = 19	POSITIVE MEAN DIFFERENCES	NEGATIVE MEAN DIFFERENCES	Z SCORE
	M	95.37	100.63	15	4	2.74**
	SD	7.14	9.42			

PHILOSOPHICAL CONTEXT	MEASURES	PRETEST N = 19	POSTTEST N = 19	POSITIVE MEAN DIFFERENCES	NEGATIVE MEAN DIFFERENCES	Z SCORE
	M	61.74	63.26	10	7	0.76
	SD	8.78	7.29			

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

TABLE 2. ACCEPTANCE OF THE THEORY OF EVOLUTION

MEASURES	PRETEST N = 19	POSTTEST N = 19	POSITIVE MEAN DIFFERENCES	NEGATIVE MEAN DIFFERENCES	Z SCORE
M	20.95	22.21	11	0	2.93**
SD	2.78	2.74			

TABLE 3. UNDERSTANDING OF APPLIED EVOLUTIONARY PRINCIPLES

MEASURES	PRETEST N = 19	POSTTEST N = 19	POSITIVE MEAN DIFFERENCES	NEGATIVE MEAN DIFFERENCES	Z SCORE
M	34.16	36.84	13	4	2.72**
SD	2.91	3.35			

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

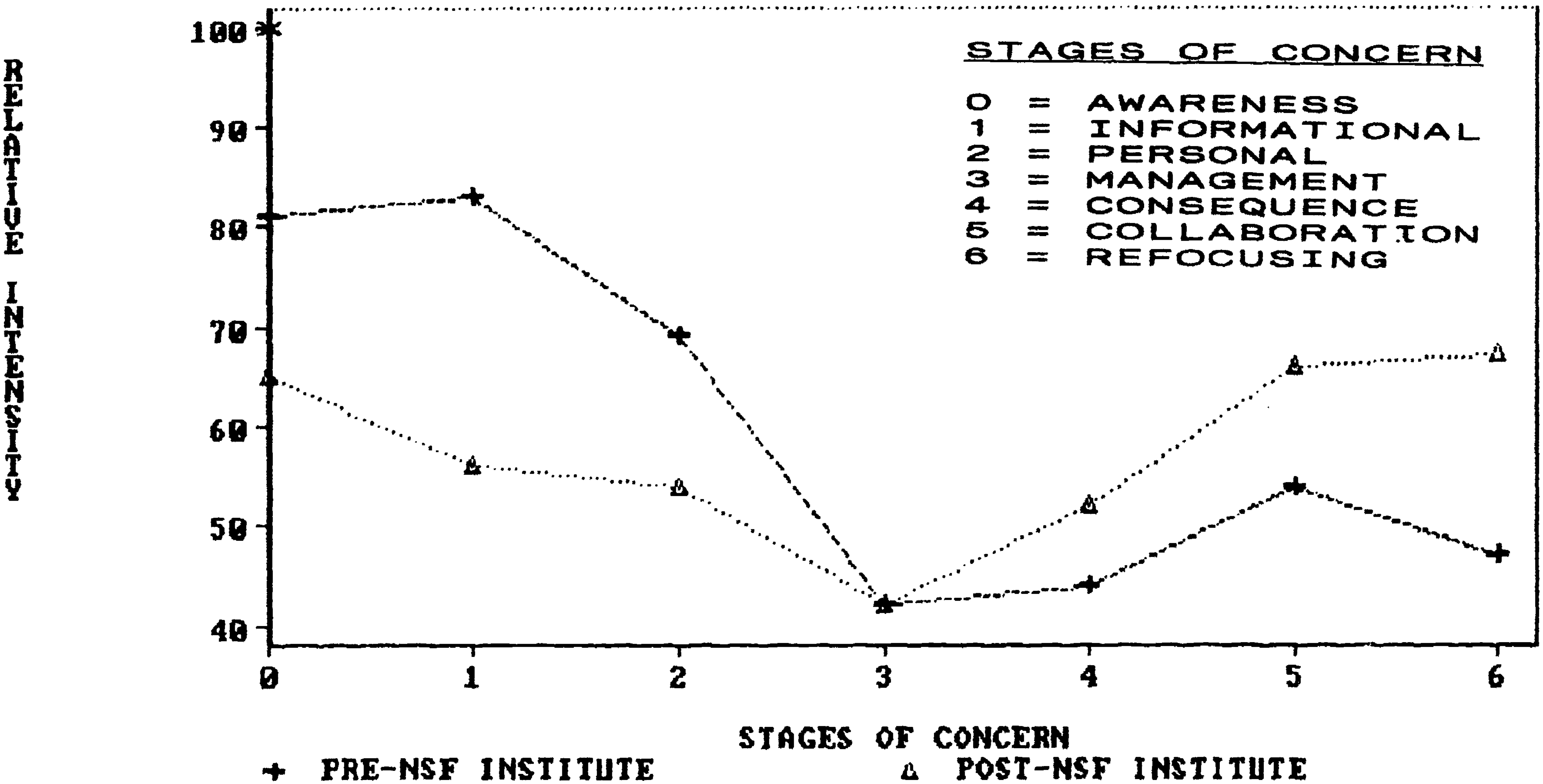
TABLE 4. CONCERNS ABOUT TEACHING EVOLUTION: "STATE" VERSUS "TRAIT" ANXIETY.

STATE ANXIETY	MEASURES	PRETEST N = 19	POSTTEST N = 19	POSITIVE MEAN DIFFERENCES	NEGATIVE MEAN DIFFERENCES	Z SCORE
	M	35.58	28.26	2	16	– 3.51***
	SD	8.51	6.41			

TRAIT ANXIETY	MEASURES	PRETEST N = 19	POSTTEST N = 19	POSITIVE MEAN DIFFERENCES	NEGATIVE MEAN DIFFERENCES	Z SCORE
	M	33.68	33.58	7	11	– 0.37
	SD	8.07	7.63			

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

FIGURE 1. USING PEER DISCUSSION AS A STRATEGY TO TEACH EVOLUTIONARY PRINCIPLES



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