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Students' Perceptions of Science Teaching and Attitudes toward Science Learning and Teachers' Self-Report of Using Children's Ideas, Applications of Science, and Use of Print Resources as Indicators of Interactive-Constructivist Teaching in Elementary Schools.

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ABSTRACT

This paper describes a study that took place within the context of the Science: Parents, Activities, and Literature (Science PALs) project. Particularly, the study sought to determine answers to the following questions: (1) What are the internal consistencies and substantive, external, and structural validities of students' perceptions, teachers' self-reports, evaluations of videotaped classroom science teaching, and expert ratings? and (2) Can students' perceptions and attitudes and teachers' self-reports be used as acceptable surrogate measures for videotaped interactive constructivist science teaching? Findings suggest that instruments based on social constructivism do not completely and accurately document science teaching based on interactive-constructivist assumptions. (Contains 30 references.) (WRM)

STUDENTS' PERCEPTIONS OF SCIENCE TEACHING AND ATTITUDES TOWARD SCIENCE LEARNING AND TEACHERS' SELF-REPORT OF USING CHILDREN'S IDEAS, APPLICATIONS OF SCIENCE, AND USE OF PRINT RESOURCES AS INDICATORS OF INTERACTIVE-CONSTRUCTIVIST TEACHING IN ELEMENTARY SCHOOLS

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Introduction

This study took place within the context of the Science: Parents, Activities, and Literature (Science PALs) Project. Science PALs was a four-year systemic reform effort collaboratively undertaken by the Science Education Center at the University of Iowa and the Iowa City Community School District and funded by the National Science Foundation (NSF) and the Howard Hughes Medical Foundation. The overarching goal of the project was to move teachers towards an interactive-constructivist model of teaching and learning that assumes a middle-of-the-road interpretation of constructivism, where hands-on activities are used selectively and purposefully to challenge students' ideas, promote deep processing, and achieve conceptual change. This model differs from the extreme interpretations of social constructivism and radical

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constructivism. As many of the teachers in the project had little or no formal knowledge of interactive-constructivist principles, the project leaders sought to provide them with opportunities to examine these principles from the vantage points of learner and teacher.

Problem

A central problem with documenting any educational innovation is selecting or developing instruments that fairly represent the theoretical innovation with valid and reliable measures. The Science PALs' version of interactive-constructivist science teaching and learning emphasized the shared roles of students, parents, and teachers regarding control, responsibilities, actions, and interactions. This perspective differs from traditional perspectives and other constructivist perspectives of science teaching and learning (Brooks & Brooks, 1993; Burry-Stock & Oxford, 1994; Yager, 1991). Traditional science instruction stresses absolute views of science, teacher control and structure, one-way communications and private mental activity, while many social constructivist perspectives stress post-modern views of science, group control and structure, two-way communications among the students directed at building consensus, and public mental activity. Therefore, it is necessary to use different documentation techniques and evaluation instruments (Searfoss & Enz, 1996). Common instruments may be used to document the basic features common among the perspectives, but additional instruments must be developed and used to document the unique features specific to any single perspective. Furthermore, it was decided that interactive-constructivist science instruction needed to be documented from a variety of perspectives of the stakeholders (teachers, students, parents, etc.) utilizing multiple methods and data sources (demographics, instructional artifacts, teacher self-reports, classroom teaching, student perceptions, parental comments, etc.). Within this problem space, the following research questions were addressed:

1. What are the internal consistencies and substantive, external, and structural validities of students' perceptions, teachers' self-reports, evaluations of videotaped classroom science teaching, and expert ratings?
2. Can students' perceptions and attitudes and teachers' self-reports be used as acceptable surrogate measures for videotaped interactive-constructivist science teaching?

Background

Science teaching, science learning, and science teacher education research has enjoyed increasing popularity in recent years with the publication of the National Research Council's *National Science Education Standards* (NRC, 1996), the *National Board for Professional Teaching Standards* (NBPTS, 1994), and the *Report of the National Commission on Teaching and America's Future* (Darling-Hammond, 1996). These documents reaffirm the importance of teachers, teaching, and hands-on/minds-on learning as primary influences on students' thinking, achievement, and science literacy. Furthermore, an analysis of the reform documents for language arts, mathematics, science, social studies, and technology revealed a common focus on "all" students, common learning outcomes of literacy and critical thinking, and common instructional intentions regarding constructivism and authentic assessment (Ford, Yore, & Anthony, 1997). Unfortunately, little attention has been given to developing concise, clear definitions of these innovations and how these desired reforms will be documented. This section attempts to clarify what interactive-constructivist science teaching involves, how it can be documented using established and new techniques, and how these new instruments can be verified.

Interactive-Constructivist Science Teaching in Elementary Schools

Constructivism, a historical view of learning that embraces much of the contemporary cognitive, sociocultural and linguistic theories, has provided a powerful foundation for addressing people's learning that behaviorism and cognitive development did not provide individually (Fosnot, 1996; Yager, 1991). Constructivism has encouraged educators to recognize the importance of ability, effort and prior performance, while also recognizing the potential influence of metacognitive awareness, self-regulation, misconceptions, sociocultural context, cultural beliefs, and interpretative frameworks. Unfortunately, the many interpretations of constructivism provide a "range of accounts of the processes by which knowledge construction takes place", but few insights into how teachers can facilitate such learning with compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5). The individual interpretations have some common assumptions and important differences: world view, view of scientific knowledge, locus of mental activity, locus of structure/control, and discourse (Yore & Shymansky, 1997).

The interactive-constructivist model of learning utilizes an ecology metaphor to illustrate learning in which dynamic interactions of prior knowledge, concurrent sensory experiences, belief systems, and other people in a sociocultural context lead to multiple interpretations that are verified against evidence and privately integrated (assimilated or accommodated) into the person's knowledge network. Interactive-constructivist approaches differ from social constructivism (which utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are verified by social negotiations resulting in consensus and common understanding at the group level) and radical constructivism (which utilizes an organism metaphor to illustrate learning in which intrapersonal deliberations and inner speech lead to equally valid unique interpretations that are internally assessed for personal consistency). Interactive-constructivist science teaching promotes a hybrid view of the world in which science is people's attempt to search out, describe, and explain generalized patterns of events in the natural world and where these descriptions, explanations, and patterns are evaluated against evidence from nature. Constructing science understanding involves both public discussions to reveal and clarify alternatives and private reflections and reconciliation to integrate these new ideas into established knowledge networks. Interactive-constructivist science instruction utilizes shared control between the teacher and students and two-way communication among students and teachers. The interactive-constructivist approach has the following attributes:

- alignment among outcomes, instruction, resources, and assessment;
- outcomes of conceptual change, conceptual growth, metacognitive strategic learning;
- does not exclude just-in-time direct instruction embedded in a natural context of need;
- supports big ideas/unifying concepts and habits of mind needed to attain scientific literacy;
- requires students to gain ability to construct understanding, to think critically, to communicate their constructions, and to persuade others of their value or utility;
- encompasses guided inquiry, learning cycles, conceptual change, and generative approaches;
- and the teaching involves accessing, engaging, experiencing/exploring, justifying/rationalizing, consolidating/integrating old and new, and applying knowledge.

If constructivism, like inquiry in the 1960s science education reform, is not clearly defined and anchored to classroom practices, it will fail to enhance science teaching and learning. Realizing the need for a well-defined instructional model, Henriques (1997) defined a prototypical interactive-constructivist elementary science teacher as having:

> a working knowledge about inquiry, the nature of science, and science topics in elementary school science. This content knowledge is married with age-

appropriate and topic-specific pedagogical knowledge (content-pedagogical knowledge) that informs instructional planning, classroom teaching, and assessment. The interactive-constructivist teacher is spontaneous, flexible, and anticipates learners' interests, questions, and problems. This teacher is committed and reflective. The interactive-constructivist teacher teaches in a holistic, contextual manner with well-defined goals and cross-curricular connections. This teacher plans interactions with literature, activities, and prior experiences (includes misconceptions) in a supportive sociocultural context in which learners talk science, share alternative interpretations, and negotiate clarity. Children's ideas are assessed, valued, and utilized to plan, to modify, and to challenge concrete experiences; and the resulting new ideas are consolidated and integrated with prior knowledge structures and related to their daily lives. The interactive-constructivist teacher implements a variety of strategies to meaningfully involve parents in their children's science and in promoting science education. This teacher is a professional and leader responsible for professional development and an advocate for science in elementary schools.

Documentation of Interactive-Constructivist Science Teaching in Elementary Schools

Yager (1991) addressed the need for documenting constructivist science teaching by developing a self-check instrument consisting of 11 dipolar dimensions based on a science-technology-society (STS) grid. He identified a variety of sociocultural groupings and problem-based tasks, their anticipated responses and results, and the associated teaching strategies as the basis for his constructivist learning model. Yager stated the "extent to which a teacher allows students to construct their own meaning will vary for teachers, individual students, and particular classrooms" (p. 56). Close inspection of the self-check instrument revealed that the dipoles represented a traditional perspective and a social constructivist perspective consistent with a STS orientation. Brooks and Brooks (1993) provided a list of eight pedagogical features dealing with curriculum, learning, teaching, assessment, and instructional groupings to contrast traditional classrooms and constructivist classrooms. Their interpretation of constructivism also appears to emphasize a social constructivist perspective. Burry-Stock and Oxford (1994) developed a science teaching evaluation model utilizing an expert-novice approach based on "a constructivist, student-centered perspective" (p. 278). Inspection of the dimensions and exemplars suggested that the constructivist perspective favors slightly a post-modern interpretation of science instruction. Collectively, the review of the related practice and literature identified four potential ways of documenting science instruction in elementary schools: expert ratings, classroom observations, students' judgments, and teachers' self-reports.

Expert Ratings

Supervision of teachers and evaluation of teaching effectiveness have historically relied on the judgments of legally recognized experts, such as superintendents, principals, directors of instruction, and content area coordinators. They are required to provide judgments of a teacher's effectiveness based on their assessments of the teacher's planning, administrative responsibilities, classroom management, teaching strategies, assessment techniques, and other identified features believed related to effective instruction. The experts' judgments involve comparing their professional conceptions of teaching and their instructional expectations with actual classroom observations of the teacher's teaching, professional interactions with the teacher, and artifacts of the teacher's instruction. Occasionally, these judgments about science instruction were unreliable, and their validities were questioned because many of the legally identified experts lacked understanding of the desired teaching, the content area, the classroom côntext, and the associated types of evidence.

Shymansky, Henriques, Chidsey, Dunkhase, Jorgensen, and Yore (1997) proposed the "professional development system" (PDS) to address these concerns about evaluating teaching effectiveness by identifying three important dimensions of instructional planning, classroom teaching, and leadership, and the associated points of evidence for each dimension. The PDS is based on the underlying assumptions of the interactive-constructivist perspective of science teaching, effective teaching (Dwyer, 1994; Shulman, 1986, 1990), and exemplary practices (Darling-Hammond, 1996). The PDS connects planning, science classroom practice, and leadership in elementary school to avoid the "tendency to ignore the substance of classroom life, the specific curriculum content and subject matter being studied" (Shulman, 1990, p. 53). Clearly judgments about elementary school science teaching effectiveness must reflect the culture of elementary schools, the context of the elementary classroom, and the unique features of the scientific enterprise.

In order to implement the PDS, definitions of quality within each dimension were developed in an iterative and collaborative manner — first relying largely on the literature. Second, conversations about proposed definitions of quality took place among the project staff, science advocates, and external consultants. The amended definitions resulting from these conversations were then re-evaluated against the research. Those definitions of quality that survived this process became the frame of reference for each performance standard. Based on experience and expertise in rating performance, confirmed by a growing literature in writing assessment in particular, the project staff elected to constrain each performance standard to four levels. The fourth, or highest level, is essentially the definition of quality for each dimension and collectively defines the desired prototype of an interactive-constructivist teacher (Henriques, 1997).

Classroom Observations

Classroom observation systems like interaction analysis, science classroom assessment procedures, and macroanalysis techniques have been used to systematically observe and code classroom actions and communications. Each of these early systems was based on specific assumptions about teaching, such as verbal interactions, inquiry learning, or emerging strategies.

Furthermore, the limitations of systems were transparent when used to document teaching that did not agree with the underlying assumptions of the instrument, such as using interaction analysis techniques to document hands-on inquiry science teaching.

The Expert Science Teaching Educational Evaluation Model (ESTEEM) is based on student-centered learning and flexible classroom structures and is designed to assess expert science teaching within social constructivist classrooms (Burry-Stock & Oxford, 1994). The social constructivism perspective is somewhat implied by the fact that a high score is achieved when students interact with each other, discuss and test their own ideas, seek consensus, and share these ideas with the teacher and by its use to document STS teaching. Most examples of students' activity is public with little evidence of the private reflection required by an interactive-constructivist approach. The constructs that each learner makes are influenced by interactions with others and cannot be separated from the sociocultural context.

Burry-Stock's (1995) Science Classroom Observation Rubric for ESTEEM has four major categories related to teaching: (a) facilitating the learning process from a constructivist perspective, (b) content-specific pedagogy (pedagogy related to students' prior understanding and understanding of targeted concepts), (c) context-specific pedagogy (adjustments in strategies based on interactions with the students) and (d) content knowledge (knowledge of subject matter). Three to six dimensions inform each category. Each dimension has five levels of teacher performance ranging from novice (1) to expert (5) and are anchored in low inference performance standards, which increases reliability and informs validity. The rubrics contain exemplars about students' behaviors and actions in addition to the teacher's behaviors and actions. The maximum score that can be earned by a teacher on the Classroom Observation Rubric is 90.

The ESTEEM rubrics were reviewed by experts in the science education community. The external reviews supported the instrument's face validity. The rubrics' validity and reliability were explored using a group of expert teachers' science classes. Forty-six Grade 4-8 teachers from seven states were selected to participate in the study. Burry-Stock and Oxford (1994) reported that the median for this group was 61, while the 25th percentile was 50 and the 75th percentile was 66. The means, standard deviations, and reliabilities were reported for the total instrument (57.30, 16.69, 0.91), facilitating learning processes (15.33, 4.81, 0.84), content-specific pedagogy (19.15, 5.12, 0.89), contextual knowledge (9.28, 2.70, 0.87), and content knowledge (13.54, 3.72, 0.80) categories.

Analysis of the ESTEEM rubrics indicated that two categories (context-specific pedagogy and content knowledge) matched the interactive-constructivist model while the other two categories (facilitating the learning process from a constructivist perspective and content-specific pedagogy) differed slightly from the interactive-constructivist model. This alignment and the psychometrics for the ESTEEM rubrics justified its use in verifying the interactive-constructivist theory and related instruments.

Students as Judges of Teaching Effectiveness

The use of students' perceptions of the constructivist teaching/learning environment to measure effectiveness is not new. Fraser (1989) reviewed 60 studies of student perceptions of constructivist teaching environments. He argued that there were several advantages to using student perceptual measures rather than observational measures, including student perceptions are based on many lessons or classes, while peer/expert observations are based on limited numbers of observations; the information obtained is the pooled judgment of all the students as opposed to the single view of an observer; and the student perception is based on the teacher's real behavior and therefore more important than inferred behavior based on observer judgment. Wilkinson (1989, p. 123) suggested that analysis of "student ratings of their teachers appeared to be as reliable as those undertaken by more experienced raters". Wagenaar (1995, p. 68) argued that students "are best at detecting consumers' perspectives on those teaching behaviors most noticeable to students".

Much of the recent work on student perceptions has been at the secondary school level with elementary schooling being overlooked (Goh & Fraser, 1995). Instruments developed at the secondary level, such as the Constructivist Learning Environment Survey (Chen, Taylor, & Aldridge, 1997), have used such factors as personal relevance, uncertainty, student negotiation, shared control, and critical voice to determine the level of student perception of the constructivist environment. Such factors are centered on the students' beliefs that the teacher encourages them to negotiate meaning, they have some control of the learning, and the study of science is more than the authoritarian view put forward by the textbook (an absolutist view of science). Goh and Fraser's (1995) study of elementary school science classrooms used the factors of leadership, helping/friendliness, understanding, student responsibility/freedom, uncertainty, dissatisfied, admonishing, and strictness as the bases for students' perceptions of the learning environment. These factors focus on teacher behavior but not necessarily all appear to be reflective of a constructivist environment. When preservice elementary teachers were asked to judge the success of constructivist teaching approaches, they chose two primary factors: "students' learning and the children's attitudes toward science" (Stofflett & Stefanon, 1996, p. 15). This would indicate that instruments designed to measure elementary students' perceptions of their teacher's implementation of constructivist approaches should incorporate these factors.

Self-Report of Teaching

Self-report, self-check, and self-regulation are established goals of the reflective teacher. Self-evaluation — although a desired goal — has been questioned for its validity and reliability since it may emphasize intent rather than actual practice. Self-evaluation and self-report appear to provide better quality information when the instruments closely reflect the shared goals and understandings of the teachers reporting. Therefore, self-report instruments need to be custom designed to a specific task involving well-defined and commonly understood assumptions and should not be the single source of information for important decisions.

Instrument Verification

Instructional innovations require a close link between model verification and instrument verification. Therefore, constructivist teaching approaches must be assessed by instruments based on the same theoretical underpinnings, reflecting specific learning environments and disciplines, and not anchored to any single established reference (Geisinger, 1992; Royer, Cisero, & Carlo, 1993). Instrument validation (validity and reliability) is an accumulative inquiry process involving the theory, the prototype and the instrument (Anastasi, 1988; Geisinger, 1992; Messick, 1989).

Validity can be considered in components: substantive, external, and structural (Yore, Craig, & Maguire, 1998). Substantive validity (face and construct) can be explored by objective expert analysis of the theory, prototype, and assessment instrument and by comparison of results of instruments to a commonly accepted reference. External validity (convergent and discriminate) can be examined by testing predictions (differences in groups expected to be different and detect changes known to exist) based on the underlying assumptions of the theory. Structural validity begins by assuming that reliable, valid data collected from the perspectives of the theory will exhibit the underlying assumptions of the theory. Factor analysis techniques can be used to examine the adequate fit of data to the fundamental structure of the model (Embretson, 1983). The goodness of fit between model and data can be explored by predetermining the number and unifying structure of the principal components revealed by the factor analysis (Loehler, 1987).

Principal components of data that closely approximate the underlying assumptions of the model are taken as supportive evidence of the model. Reliability is an integral part of structural validity and intimately connected to factor analysis approach.

Design

The research questions were addressed using a case study of the science advocates for each of the 16 elementary schools in the Iowa City Community School District. These science advocates were elementary school teachers willing to serve as science leaders in their schools and to participate in the Science PALs project. Multiple methods were used to collect data on the science advocates' implementation of the Science PALs' goals (expert ratings), their classroom teaching (ESTEEM), their self-perceptions (self-reports), and their impact on students (students' perceptions and attitudes). These data were collected during the 1995-96 school year. Complete data sets were developed for 14 science advocates since 2 science advocates left the school district and the project.

Instruments

Constructivist classrooms look different than their traditional counterparts. The students and teachers have different roles. As a result, traditional forms of teacher evaluation and measurement do not work well for constructivist classrooms (Searfoss & Enz, 1996). The first problem encountered in this study was to select and develop instruments that accurately reflected the interactive-constructivist theory. Techniques established to measure social constructivist practices will not fully document the interactive-constructivist perspective. As a result, something else had to be used, while attempting to anchor the new instruments to the established instruments. The Professional Development System (PDS) was collaboratively developed by the science advocates, project staff, and external consultants (Shymansky, et al., 1997). The PDS guided the selection and development of instruments since it represented the underlying assumptions of the interactive-constructivist approach and was commonly understood by the science advocates, experts, and project staff involved in this study.

Expert Ratings

The advocates' implementation of the Science PALs approach was globally assessed by four expert staff members who had been involved in the development and calibration of the PDS (Director of Professional Development, Science Coordinator, and two graduate student staff members). Each expert had strong science content background and considerable experience with elementary school teachers and science instruction. They were asked to rank order the 14 advocates remaining in the project at the end of year 2 (1996) on their overall implementation of the interactive-constructivist approach, use of children's ideas, use of children's literature, and knowledge of reforms and misconceptions. The raters based their ratings on work with the science advocates in professional development activities and in their classrooms. There was 75% agreement (3 or more experts agreed within 1.5 positions in the rank order) among the four raters on the top 4 and bottom 4 advocates, while only 33% of the ratings of the middle 6 advocates reached this level of agreement (Henriques, 1997). Therefore, an average rating was calculated for the four ratings.

ESTEEM Ratings of Science Teaching

The ESTEEM rubric was used to evaluate two videotaped science lessons provided by each science advocate. The videotapes were scored by two of three independent experts (Henriques, 1997). One of these experts had significant experience with the ESTEEM rubric from another research project. This expert trained the other two science educators to use the ESTEEM rubric. Drastic differences in scoring (±5 points on the total score) of a videotape resulted in discussion between the experts and rescoring when consensus could not be reached. The higher total ESTEEM score for the two science lessons was used to represent the advocate's teaching for this analysis. The ESTEEM scores ranged from 39 to 85 with an average of 61.07.

Students' Perceptions of Science Teaching and Attitudes toward Science Learning

Students' perceptions of science teaching was composed of (a) view of constructivist approach, (b) parents' interest, (c) teacher's use of children's literature in science, and (d) relevance of science. Students' attitudes toward science learning was composed of (a) attitudes towards school science, (b) self confidence, (c) nature of science, and (d) science careers. These domains and subscales were assessed using Likert items to determine the students' agreement, lack of awareness, or disagreement with specific statements about each factor. The items were developed by the project staff and external consultants to reflect the established features of the science reform and the project. The subscales were established using factor analyses techniques. Original items were scored as disagree (1), do not know (2), and agree (3) and were assigned to factors using a varimax approach with minimum loading weights of 0.30. Items not meeting this condition were deleted, resulting in a final Grades 1-2 survey of 37 items, Grades 3-4 survey of 57 items, and Grades 5-6 survey of 72 items. Table 1 provides the number of items in each factor and the internal consistency based on data collected for Grades 1-2, 3-4, and 5-6 in the spring of 1996. Internal consistencies ranged from marginal (0.45-0.60) on 18 data sets to reasonable (0.61-0.88) on 42 data sets. Generally, the instruments have reasonable validities (substantive and structural) and reliabilities for exploratory research, but further verification will result from this study.

Teachers' Self Reports

The science advocates' perceptions of their science planning, teaching, and assessment were assessed by Likert items designed to assess strong disagreement (1), disagree (2), neutrality

Table 1
Internal Consistencies of and Number of Items in the Likert Item Factors used to Assess Students' Perceptions and Attitudes

	Grade-Level Groupings		
Scale and Factors	1-2	3-4	5-6
Perceptions of Science Teaching	0.83(20)	0.85(34)	0.88(35)
Constructivist Approach	0.67(8)	0.81(21)	0.85(17)
Parental Interest	0.70(6)	0.68(5)	0.72(7)
Use of Literature in Science	0.52(3)	0.49(3)	0.61(5)

Relevance of Science	0.50(3)	0.56(5)	0.74(6)
Attitudes toward Science Learning	0.71(17)	0.79(23)	0.84(37)
Attitude toward School Science	0.58(6)	0.74(5)	0.81(21)
Self-concept	0.54(3)	0.64(6)	0.63(6)
Nature of Science	0.60(4)	0.53(9)	0.51(7)
Careers in Science	0.68(4)	0.72(3)	0.79(4)

(1996 data: $N_t = 2552$, $N_{1-2} = 831$, $N_{3-4} = 722$, $N_{5-6} = 999$)

(3), agree (4), or strong agreement (5) with specific ideas on a 5-point scale. The items were developed by the project staff and external consultants to reflect the underlying assumption of the project. A factor analysis of these items revealed 32 items with reasonable factor loadings (0.30) and conceptual unity fit a 3-factor solution. The first factor consisted of 17 items related to using children's ideas in planning and teaching with an internal consistency of 0.88. The second factor consisted of 10 items related to the application of science to the children's daily lives with an internal consistency of 0.82. The third factor consisted of 5 items related to the use of print resources with an internal consistency of 0.73. These three self-report dimensions closely parallel the pedagogical emphasis of Science PALs — using children's ideas, relevance, and using children's literature. The instrument was judged to have reasonable validities (substantive and structural) and reliabilities for exploratory research.

Data Analyses and Results

The research focus of this study was to verify the use of students' perceptions and attitudes and teachers' self-report information as measures of interactive-constructivist science teaching in elementary schools. The analyses provide descriptive data, correlations, ANOVAs, and T-tests for 14 science advocates who have been involved in the Science PALs project. The correlations between these measures and established instruments (expert ratings and ESTEEM ratings) provide an indication of substantive validity (construct). Differences in ESTEEM scores, perceptions, attitudes, and self-report information for 3 groups of advocates based on the expert ratings were tested using Analyses of Variance (ANOVA) and T-tests as indications of external validity. Tables 2, 3, and 4 provide descriptive statistics, correlations, summary ANOVAs, and pair-wise T-tests for each measure.

The expert ratings were based on the judgments of the 4 well-informed science educators and on numerous encounters with the 14 science advocates' instructional planning, teaching, and leadership. There was 68% agreement (±1.5 positions in rank order for 3 of the 4 experts) among the science educators. The variability was expected since each expert viewed the science advocates' implementation from slightly different perspectives, but their collective judgment (average rating) was believed to be the best indicator of the science advocates' overall implementation of the interactive-constructivist approach.

The ESTEEM scores indicate that the science advocates do not fully reflect the social constructivist perspective implicit in the instrument. The average ESTEEM score for the advocates teaching (61.07) is slightly higher than the average ESTEEM score for the 46 expert science teachers (57.30) used to norm the instrument (Burry-Stock & Oxford, 1994). Only one advocate with a score of 85 appears to approximate the teaching strategies implied by the ESTEEM rubric. Most science advocates (12) have middle-of-the-road scores (55 to 75) that are characteristic of a shared-control but learner-focused teaching style implied by the prototypical interactive-constructivist teacher. The interactive-constructivist teaching approach has many common expectations with the ESTEEM model, but it is unlikely that an interactive-constructivist teacher would score in the 80-90 range on the ESTEEM rubric.

The students' perceptions of their teacher's teaching were slightly positive to positive (2.08-2.67), while students' attitudes toward science learning were somewhat more positive (2.19-2.63). Teachers self-reported use of students' ideas, applications of science to the children's world, and use of print resources were positive (3.63-4.07). Close inspection of Table 2 illustrates a general pattern among the science advocates identified by the experts' ratings as low-level implementors, middle-level implementors, and top-level implementors in

Table 2
Means of Science PALs Advocates for Specific Measures of Constructivist Teaching

	Level of Implementation		
Measure	Low (N = 4)	Middle (N = 6)	Top (N = 4)

ESTEEM	55.00	61.83	71.00
Students' Perception of Science Teaching (SPST)	2.40	2.33	2.50
Students' View of Constructivism (SVC)	2.66	2.58	2.77
Parental Interest (SPI)	1.99	1.93	2.14
Use of Literature (SUL)	1.55	1.50	2.20
Relevance (SR)	2.71	2.68	2.41
Students' Attitude toward Science Learning (SASL)	2.46	2.41	2.42
Students' Attitude toward School Science (SASS)	2.20	2.19	2.64
Students' Self-concept (SSC)	2.66	2.67	2.53
Nature of Science (SNS)	2.84	2.73	2.06
Careers in Science (SCS)	2.08	2.08	2.47
Teachers using Children's Ideas (TUCI)	3.49	3.43	3.66
Teachers' Applications to Children's World (TACW)	3.81	3.83	3.73
Teachers using Print Resources (TUPR)	3.25	3.21	4.04

which the middle-level group frequently has lower student perceptions, student attitudes, and self-reports than do the low-level and top-level implementors. The top-level implementors have the highest values on 8 measures while the low-level implementors have the highest value on 5 measures.

Table 3

Inter-measure Correlation Matrix

	Expert Ratings	ESTEEM	SPST	SVC	SPI	SUL	SR	SASL	SASS	SSC	SNS	SCS	TUCI	TACW
ESTEEM	0.68**													
SPST	0.28	0.08												
SVC	0.30	-0.02	0.90***											
SPI	0.34	0.03	0.94***	0.83***										
SUL	0.58*	0.23	0.72**	0.67**	0.76**									
SR	-0.40	0.04	-0.04	-0.25	-0.21	-0.61								
SASL	-0.12	0.01	0.48	0.37	0.25	-0.03	0.66*							
SASS	0.66**	0.27	0.64**	0.59*	0.60*	0.81***	-0.31	0.26						
SSC	-0.37	-0.10	0.08	0.10	-0.08	-0.47	0.61*	0.61*	-0.38					
SNS	-0.63*	-0.13	-0.31	-0.38	-0.47	-0.80***	0.85***	0.50	-0.66**	0.69**				
SCS	0.62*	0.19	0.46	0.52	0.45	0.78***	-0.54*	0.08	0.86***	-0.50	-0.73**			
TUCI	0.26	-0.11	0.44	0.38	0.43	0.51	-0.22	0.36	0.44	-0.03	-0.18	0.42		
TACW	-0.08	-0.33	0.06	0.05	0.09	0.26	-0.29	0.09	0.06	-0.09	-0.09	0.30	0.73**	
TUPR	0.50	0.23	0.40	0.29	0.40	0.60*	-0.26	0.22	0.68**	-0.34	-0.39	0.56*	0.68**	0.21

* denotes $p \leq 0.05$

** denotes $p \leq 0.01$

*** denotes $p \leq 0.001$

Table 4
Summary ANOVAs and Pair-wise T-tests for Three Groups of Science Advocates
Based on their Perceived Implementation of Science PALs

	ANOVAs		Pair-wise Comparisons					
			Top vs. Low		Top vs. Middle		Middle vs. Low	
Measure	F-ratio	P-value	T-value	P-value	T-value	P-value	T-value	P-value
ESTEEM	440.20	0.001	29.22	0.001	11.62	0.001	22.32	0.001
SPST	2.47	0.134	1.14	0.279	2.22	0.051	-0.98	0.351
SVC	4.05	0.052	1.55	0.152	2.84	0.017	-1.15	0.277
SPI	2.30	0.151	1.37	0.120	2.14	0.050	-0.64	0.538
SUL	39.99	0.001	7.20	0.001	8.45	0.001	-0.55	0.596
SR	2.78	0.109	-2.11	0.061	-2.05	0.067	0.26	0.800
SASL	0.27	0.769	-0.52	0.617	0.15	0.881	-0.72	0.488
SASS	12.13	0.002	4.03	0.002	4.59	0.001	-0.16	0.875
SSC	1.67	0.236	-1.47	0.174	-1.72	0.146	0.11	0.911
SNS	9.11	0.006	-3.87	0.003	-3.66	0.004	-0.59	0.569
SCS	14.78	0.001	4.55	0.001	4.98	0.001	-0.01	0.996
TUCI	0.55	0.594	0.69	0.508	1.04	0.323	-0.29	0.776
TACW	0.18	0.840	-0.43	0.675	-0.58	0.573	0.11	0.914
TUPR	3.62	0.066	2.18	0.054	2.52	0.030	0.13	0.899

The correlation between the ESTEEM scores and the expert ratings was significant ($p \leq 0.01$). The inter-measure correlations revealed disappointing relationships between ESTEEM and students' perceptions, students' attitudes, and teacher's self-report information. The relationships between expert ratings and the students' perceptions, students' attitudes, and teacher's self-report information is somewhat more promising. These results support the expectation that the ESTEEM instrument emphasized a slightly different perspective of constructivism than the interactive-constructivist approach. Furthermore, these results suggest that the students' perceptions and attitudes and the teacher's self-report instruments need fine-tuning to increase their substantive validities.

Significant ($p \leq 0.05$) main effects in the ANOVAs were found for ESTEEM, students' view of constructivist approach, students' perception of use of literature in science, students' attitude toward school science, students' attitude toward the nature of science, students' attitude toward careers in science, and teachers' report of using print resources. The pair-wise t-test comparisons for these significant main effects reveal that 7 differences between the top-level implementors and middle-level implementors account for most of the main effects. Most frequently, the difference favored the top-level implementors (except students' self-concept in science). Six differences between the top-level and low-level implementors were found significant. All but one difference (students' self-concept in science) favored the top-level implementors. The only significant difference between middle-level and low-level implementors was for the total ESTEEM scores.

Discussion

This study supported the anticipation that instruments based on social constructivism would not completely and accurately document science teaching based on interactive-constructivist assumptions. The correlations between experts' ratings and ESTEEM ($r = 0.68$) and the ANOVA and pair-wise t-tests of ESTEEM differences for groups specified by their expert ratings were significant, but sizable amounts of variance (54%) were not accounted for by the social constructivist-based instrument.

This study also revealed that some students' perceptions of science teaching (view of constructivism, parental interest, and using literature in science) and attitudes toward science learning (attitudes toward school science and careers in science) have reasonable validities and reliabilities to use as indicators of interactive-constructivist teaching. Teachers' self-reports of using children's ideas and use of print resources also have potential as indicators of interactive-constructivist teaching. Students' perceptions of relevance and self-concept, self-concept in science, and attitudes toward nature of science and teachers' self-report of applications of science to the children's daily lives appear to distract from the instruments' substantive and external validities. Eliminating or revising these dimensions should improve the overall utility of these instruments.

Analysis of each dimension (item) within the 4 categories of the ESTEEM rubric suggests that some items could be revised or the exemplars revised to more closely reflect an interactive-constructivist perspective of elementary school science teaching. Revisions would require new expert exemplars for student engagement in activities, novelty, textbook dependency, student relevance, and higher order thinking skills. Another solution might be to establish an ideal ESTEEM score for the prototypical interactive-constructivist teacher (i.e., 85) and to express ESTEEM scores as a positive or negative deviation score about the idealized ESTEEM score. This would allow changes in teaching to be defined as growth toward the ideal score.

This study of 14 science advocates' teaching, their students' perceptions and attitudes, and their self-reports indicates that students can detect some differences and some self-reported information matches external judgments. If the two instruments are revised, they can be efficient and effective surrogate measures of interactive-constructivist science teaching in elementary schools.

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