April 1998

Students' Perceptions and Supervisors' Rating as Assessments of Interactive-Constructivist Science Teaching in Elementary School.

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DOCUMENT RESUME

ED 418 876		SE 061 357

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TITLE	Students' Perceptions and Supervisors' Rating as Assessments of Interactive-Constructivist Science Teaching in Elementary School.
SPONS AGENCY	National Science Foundation, Arlington, VA.
PUB DATE	1998-04-21
NOTE	29p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (71st, San Diego, CA, April 19-22, 1998).
CONTRACT	ESI-9353690
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Constructivism (Learning); Elementary Education; Elementary School Science; Instructional Innovation; Learning Strategies; Misconceptions; *Science Course Improvement Projects; *Science Teachers; *Student Attitudes; *Student Evaluation of Teacher Performance; Teacher Evaluation; Teaching Methods
IDENTIFIERS	Iowa City School District IA; National Science Education Standards; Systemic Educational Reform

ABSTRACT

This study took place within the context of a four-year local systemic reform effort collaboratively undertaken by the Science Education Center at the University of Iowa and the Iowa City Community School District. The 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. The research focus of this study was to verify the use of students' perceptions and attitudes and the supervisor's ratings as measures of teachers' implementation of interactive-constructivist teaching in elementary classrooms. The question was addressed using a case study of 52 elementary science teachers. This convenience sample was defined by the professional judgment of the expert rater using an eight-dimension checklist/rating rubric. Students' perceptions and attitudes and expert ratings of constructivist science teaching had marginal external validity. Includes in-depth discussion of constructivism and interactive-constructivist teaching. (Contains 46 references and 5 tables.) (PVD)

Students' Perceptions and Supervisors' Rating as Assessments of Interactive-Constructivist Science Teaching in Elementary School

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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 (1994-1998) local 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

Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Diego, CA, April 19-22, 1998.

This paper is based upon research supported by the National Science Foundation under Grant No. ESI-9353690. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.

selectively and purposefully to challenge students' ideas, promote deep processing, and achieve conceptual change.

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 various faces of constructivism appear to have some common features and some fundamental differences (Shymansky, Yore, Dunkhase, & Hand, 1998). 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 (Yore, Shymansky, Henriques, Hand, Dunkhase, & Lewis, 1998). 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. It was decided therefore, that interactive-constructivist classroom instruction needed to be documented from both teachers' and students' perspectives utilizing efficient, non-disruptive methods and data sources — expert ratings and students' perceptions and attitudes (Searfoss & Enz, 1996). Within this problem space, the following research question was addressed:

> What are the internal consistencies and substantive, external, and structural validities from the perspectives of students and experts regarding the level of implementation of constructivist science teaching philosophies and strategies?

Context

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 (NCTE/IRA, 1996), mathematics (NCTM, 1989; 1991), science (AAAS, 1993; NRC, 1996), social studies (NCSS, 1994), and technology (ITEA, 1996) 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.

The Faces of Constructivism

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, language, 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" and few insights into how teachers can facilitate such learning with compatible teaching and assessment approaches (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 5).

Essentially four faces of constructivism have been identified in the science education literature: an information processing face, a group consensus-socially negotiated face, a radical-idiosyncratic face, and an interactive-evidence based face (Henriques, 1997; Phillips, 1995; Matthews, 1994). The information processing face utilizes a computer metaphor to illustrate learning in which a series of micro-processes generates ideas and analyzes errors, which lead to closer and closer approximations of the right answer. Learning is a process of identifying causal relationships between antecedents and outcome, establishing critical (essential, necessary, and sufficient) attributes of a concept, and acquiring accurate understanding of fixed entities and relationships that exist independent of human activity.

The social constructivism face utilizes a context metaphor to illustrate learning in which group dynamics lead to multiple interpretations that are resolved by social negotiations resulting in consensus and common understanding at the group level. Knowledge is perceived as a social artifact, not as a representation of reality.

The radical constructivism face 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. Knowledge is perceived as an idiosyncratic snapshot of reality.

The interactive-constructive face 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. Knowledge is perceived as individualistic conceptions that have been verified by the epistemic traditions of a community of learners.

The four faces of constructivism share some common basic assumptions, while the individual faces have important differences. The four faces agree that understanding is actively made out of, invented from, or imposed on personal experiences (Fosnot, 1996). The construction processes and the resulting constructs are influenced by the learners' prior knowledge, memory, cognitive abilities, metacognition, interpretative framework, and sociocultural context. Each face encourages meaningful learning of integrated knowledge networks through active debate and reflection, and each has discounted rote learning and drill-practice. Furthermore, each face agrees that people have misconceptions within their prior knowledge and that these misconceptions are not indications of stupidity; are found across age groupings, content areas, cultures, and national boundaries; and are resistant to change. Replacement of misconceptions with more scientifically acceptable conceptions requires that the misconception is engaged and challenged and that the new concept be sensible, rational, usable, and powerful.

The individual faces of constructivism, however, differ in their philosophical, psychological, epistemological, and pedagogical underpinnings (Yore & Shymansky, 1997). Each face assumes unique views of how the world works (worldview); what knowledge is and how it comes to be (view of knowledge); where meaning-making occurs (locus of mental activity); who is in control of learning (locus of control); and what is the nature and purpose of classroom interactions (view of discourse). Each of these is described further and then summarized in Table 1.

Worldview involves ways of thinking about how the world works (Prawat & Floden, 1994). Mechanistic views stress the important role of antecedent events as influence on behavior. Contextualistic views stress the importance of situation and environment where the meaning of an act may have situation-specific features, may undergo changes as it unfolds in a dynamic environment, and the pattern of events in a sociocultural context have low predictability. Organistic views stress the importance of the organism as a whole. Reality is only what the organism subjectively perceives; knowing is an individualistic event. Hybrid views stress the importance of interactions with the physical world (natural and people-built) as well as the sociocultural context and recognize that interpretations reflect lived experiences and cultural beliefs of the knowers.

View of knowledge (in science) represents the ontological structure of knowledge and epistemic ways of knowing (Hofer & Pintrich, 1997; Kuhn, 1993). Those with an absolutist view hold that there is a single right answer to be sought and proven. Those with an evaluative view hold that knowledge is the result of testing different interpretations and supporting or disconfirming ideas on the basis of argument and evidence. Those with a relativist view hold that multiple interpretations of events are equally valid.

Locus of mental activity represents the beliefs about where negotiated meaning and understanding occurs — privately within the learner or publicly within the learning group. Advocates of private meaning-making hold that it occurs deep within the mind and brain of the individual (activity flows from periphery to core where irrelevant stimuli are discarded leaving abstract representations of critical and essential information or activity focuses on subjective experiences, extracting internal coherence and where rightness is seen as the fit with personally established order). Advocates of public meaning-making hold that it occurs within the dynamics of the group (activity is on the interface between the individual and the environment where the collective wisdom of the group and craft knowledge of the community construct understanding). Advocates of an interactive public-private meaning-making view hold that multiple meanings are exposed, clarified, and narrowed in group negotiations but that actual meaning is made privately by individuals reflecting on, reconciling, and consolidating these possibilities (Hennessey, 1994; Prawat & Floden, 1994).

Locus of control/structure represents a pedagogical feature and the pragmatics of classroom teaching dealing with who sets the agenda for study within a specific epistemology — teachers, students, or both. An implicit source of structure imposed on the learning comes from the content area under consideration: physical sciences or biological sciences (Yore, 1984; 1986).

Discourse represents the combined psychological-pedagogical feature of type and purpose of communications in the classroom — one-way interpersonal communications of expert to novice, one-way intrapersonal communications of person to self (inner speech the language tool of thinking and spontaneous conception), and two-way interpersonal communications among people to negotiate clarity or to establish consensus (Fosnot, 1996; Prawat & Floden, 1994).

A Vision of Interactive-Constructivist Teaching

The vision described in the *National Science Education Standards* (NRC, 1996) is of science teaching that engages all students in a quest for science literacy involving the abilities and habits-of-mind to construct understanding of the big ideas and unifying concepts of science and the communications to share their understandings and persuade other people about these ideas (Ford, et al., 1997). The science teaching standards envision changes in emphasis (NRC, 1996, p. 52):

Less Emphasis on	**More Emphasis on**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry

Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

When these changing emphases in teaching (children's attributes, rigidity of curriculum, relevant learning outcomes, active quest, alternative assessment, locus of control, and collaboration) are considered in the context of science and technology standards (science as inquiry and technology as design) and the epistemology described by the nature of scientific knowledge standards ("Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for best possible explanations about the natural world"), it becomes apparent that an interactive-constructivist perspective is supported by the *National Science Education Standards* (NRC, 1996, p. 201).

Interactive-constructivist approaches differ from social constructivism and radical constructivism mainly in its view of science, the public and private aspects of learning, the shared control of instruction, and the role of discourse. Interactive-constructivist science teaching promotes a view of science in which people 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, reconciliation, and consolidation 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 (Henriques, 1997):

- alignment among outcomes, instruction, resources, and assessment;
- outcomes of conceptual change, conceptual growth, and metacognitive strategic learning;
- does not exclude just-in-time direct instruction embedded in a natural context of inquiry and student 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;
- 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 model, Henriques (1997) defined a prototypical interactive-constructivist elementary science teacher as having (not an exact quote, p. 117):

> 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 to form 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.

Documenting 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 (ESTEEM) 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. Comparison of the ESTEEM examples and the interactive-constructivist prototype revealed disagreement for the student engagement in activities, novelty, textbook dependency, student relevance, and higher order thinking skills dimensions of the facilitating learning and the content-specific pedagogy categories.

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. A study of 14 elementary school teachers' science teaching revealed that expert ratings and 5 students' perceptions and attitudes had potential for documenting interactive-constructivist science teaching (Yore, Shymansky, et al., 1998). ESTEEM ratings of videotaped science teaching were significantly correlated to the expert ratings but not well associated with students' perceptions and attitudes and teachers' self-reported perceptions. The use of videotaped science teaching was not well received by classroom teachers, and there were logistical difficulties and technical quality problems with videotaping activity-oriented group work in many regular elementary school classrooms. Based on these earlier results, expert rating and students' perceptions and attitudes were focused on for this study.

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 supervisors. 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 context, and the associated types of evidence.

Shymansky, Henriques, Chidsey, Dunkhase, Jorgensen, and Yore (1997) proposed the professional development system (PDS) to address reliability and validity 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 (teachers from each elementary school responsible for modeling and promoting effective science teaching), 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 of quality. 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, pp. 164-187).

With the earlier results (Henriques, 1997; Yore, Shymansky, et al., 1998) and a clear vision of the Science PALs prototype, it became apparent that expert ratings could be improved if more well-developed analytical checklists or rubrics were developed for the basics of constructivist approaches and for the unique features of the interactive-constructivist approach, which promoted shared understandings and focused judgments. An 8-dimension checklist/rating rubric was developed. The rubric required the rater to assess the degree of compliance (very weak, weak, satisfactory, strong, or very strong) with the following dimensions:

1. Depth of content knowledge and content-pedagogical knowledge on science topics taught.
2. Knowledge of the reform standards and focus on fewer, big ideas as a part of connected whole rather than on coverage of isolated ideas.
3. Use of strategies to access and utilize information on student ideas in planning instruction.
4. Use of strategies to challenge student ideas and to have them reflect on and integrate those ideas into their thinking.
5. Use of strategies that routinely and continuously incorporate children's literature and personal experiences as context for learning science.
6. Use of strategies that promote ongoing, substantive parent involvement in the science instruction.
7. Use of strategies that promote development of reading, writing, and speaking skills in the context of science instruction
8. Overall rating as a constructivist teacher, as defined in the goals of the Science PALs program.

Dimensions 1-4 represent common basic features across several interpretations of constructivism, while dimensions 5-7 represent unique features of the interactive-constructivist approach and dimension 8 represents a holistic assessment of the Science PALs prototype.

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 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 external 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 little consideration of elementary schools (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 focused 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 (1995) used the factors of leadership, helping/friendliness, understanding, student responsibility/freedom, uncertainty, dissatisfied, admonishing, and strictness as the foundations for students' perceptions of the elementary school science learning environment. These factors focus on teacher behavior but some do not 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.

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 question was addressed using a case study of 52 elementary teachers from the Iowa City Community School District who teach science. The convenience sample was defined by the professional judgment of the expert rater. The expert was asked to identify from a list of all elementary school teachers in the host school district those teachers she believed had enough professional experience with and insights into their science teaching that she could provide a defensible judgment of their science teaching on the 8 dimensions described earlier. The expert's decision was based on consultative, classroom, and professional development experiences. Two methods were used to collect data on these science teachers' use of constructivist and interactive-constructivist approaches (expert ratings) and their impact on students (students' perceptions and attitudes). These data were collected during April-June 1997.

Sample

The 52 teachers involved in this study represented all 16 elementary schools in the Iowa City Community School District. These teachers taught science in Grades 1-2 (N = 13), 3-4 (N = 22), and 5-6 (N = 17) to 1,315 students who completed the student perception and attitude survey. All teachers were well known by the science supervisor for the school district and the field coordinator of the Science PALs project, who had several formal and informal opportunities to experience these teachers' philosophy about science teaching and their learning and science pedagogy.

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, adapt, and develop instruments that accurately reflected the constructivist and interactive-constructivist theories. 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 PALs participants, the 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 expert, project staff, and external consultants involved in this study.

Expert Ratings

The elementary teachers' implementation of the Science PALS approach was assessed by the science supervisor who had been involved in the development and calibration of the PDS. The science supervisor had strong science content background and considerable experience with elementary school teachers and science instruction. She was asked to assess selected teachers remaining in the project at the end of year 3 (1997) and other teachers not in the project on their implementation of basic constructivist ideas, the specific interactive-constructivist ideas, and overall Science PALs prototype of science teaching. The expert based her ratings on work with the teachers in professional development activities and in their classrooms.

Likert scores for the individual items on the rating form were factor analyzed to verify the two dimensions built into the instrument a priori: (1) Constructivist Rating (CR) — the expert's rating of the teachers' understanding and use of common constructivist principles and (2) Interactive-Constructivist Rating (ICR) — the expert's rating of the teachers' implementation of strategies peculiar to the interactive-constructivist approach used in the Science PALs project (i.e., use of parent partners to assist in assessing students' prior knowledge and the use of children's literature to frame hands-on activities to challenge student ideas). The CR (dimensions 1-4 and 8) and ICR (dimensions 5-7) scales emerged from the factor analysis with loadings of 0.30 or greater. Since dimension 8 did not factor into a separate component, the CR and ICR scales were then combined to create an overall Science PALs Rating (SPR).

The CR and ICR values were then forced into a distribution from which a three-group classification was generated using a clustering of one standard deviation above and below the mean of the CR and the ICR as the cut-off points. The resulting 3-point rating system for the CR and ICR dimensions was then used in checks for inter-rater reliability between two well-informed raters. There was 62.5% exact agreement and 100% near agreement (within 1.0 position) between the independent assessments of the science supervisor and the Science PALs' field coordinator for the 52 teachers using the CR scale. There was 65.47% exact agreement and 100% near agreement on the ICR scale. The inter-rater correlations for the CR and ICR scales were 0.62 and 0.72. The overall SPR was defined as a 5-point scale comprised of the combined CR and ICR values. An SPR of 1 was assigned to teachers with a 1 rating in both CR and ICR, 2 was assigned to teachers with a 1 rating in one scale and 2 in the other scale, 3 was assigned to teachers with 2 ratings in both scales, 4 was assigned to teachers with a 2 rating in one scale and 3 rating in the other scale, and 5 was assigned to teachers with 3 ratings in both scales.

Students' Perceptions

Students' perceptions of science teaching was originally 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 (Dunkhase, Hand, Shymansky, & Yore, 1997). Students' attitudes toward science learning was originally 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 Science PALs 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. The substantive and external validities were explored using 1996 data from 14 science advocates' classrooms (Yore, Shymansky, et al., 1998). The results suggested that the students' perceptions of relevance and the students' attitudes toward the nature of science and self-concept in science should be deleted. Table 2 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 and 1997. Generally, the instruments have reasonable validities (substantive, external, and structural) and reliabilities for exploratory research, but further verification will result from this study.

Data Analyses and Results

The research focus of this study was to verify the use of students' perceptions and attitudes and supervisor's ratings as measures of teachers' implementation of constructivist, interactive-constructivist, and Science PALs teaching in elementary schools. The analyses provide descriptive data, ANOVAs, and t-tests for 52 elementary teachers and their students.

Tables 3, 4, and 5 provide the descriptive statistics for students' perceptions and attitudes from teachers' classrooms with different CR, ICR, and SPR values. Tables 3 and 4 illustrate three groups of teachers that rated low (1), middle (2), and high (3) on their implementation of constructivist teaching and their interactive-constructivist teaching. Table 5 illustrates four groups of teachers based on their overall implementation of the Science PALs teaching. The small number of teachers with ratings of 1 on one scale and 2 on the other scale and ratings of 2 on both scales required that these two groups be collapsed into a single category 2-3. Inspection of these data reveals a general non-linear trend in which teachers with middle ratings appear to have less impact on students' perceptions and attitudes than teachers with low and high ratings.

Predicted differences in students' perceptions and attitudes for groups of teachers based on the expert ratings were tested using Analyses of Variance (ANOVA) and pair-wise t-tests as indications of external validity. These results reveal occasional significant main effects for students' perceptions and rather consistent significant main effects for students' attitudes.

Significant CR main effects for students' perceptions of the constructivist approach ($F = 4.13$, $df = 2,1225$, $p = 0.016$), attitude toward science learning, ($F = 2.91$, $df = 2,1225$, $p = 0.055$) and attitude toward school science ($F = 3.81$, $df = 2,1225$, $p = 0.022$) were found. Pair-wise t-test comparisons of differences within these significant CR main effects revealed inconsistent patterns. Students' perceptions of the constructivist approach revealed that students from teachers' classrooms rated 1 and 2 were significantly ($p \leq 0.05$) higher than for those from classroom rated 3. Students' attitudes toward science learning from teachers' classrooms rated 3 were significantly higher than from classrooms rated 2. While the students' attitudes toward school science were significantly higher from teachers' classroom rated 1 and 3 than from teachers' classrooms rated 2.

Significant ICR main effects for students' perceptions of parent interest ($F = 3.07$, $df = 2,1225$, $p = 0.047$), perceptions of the use of literature ($F = 3.10$, $df = 2,1225$, $p = 0.046$), attitude toward science learning ($F = 4.97$, $df = 2,1225$, $p = 0.007$), and attitude toward careers in science ($F = 5.51$, $df = 2,1225$, $p = 0.005$) were found. The pair-wise comparisons of differences within these significant ICR main effects revealed somewhat more consistent patterns in which students' perceptions of parent interest and the use of literature and students' attitudes toward science learning and careers in science were higher or significantly ($p \leq 0.05$) higher for teachers rated 3 than for teachers rated 1 (except parental interest where teachers' students rated 1 had slightly higher ratings than those rated 3). Teachers rated 2 generally were significantly lower than teachers rated 1 or 3 (except use of literature).

Significant SPR main effects for students' attitudes toward science learning ($F = 3.66$, $df = 3,1219$, $p = 0.012$), school science ($F = 2.59$, $df = 3,1219$, $p = 0.052$), and career in science ($F = 3.28$, $df = 3,1219$, $p = 0.020$) were found. The pair-wise comparisons of differences within these significant main effects revealed that students' attitudes from classrooms with teachers rated 2 or 3 were significantly ($p \leq 0.05$) lower than the attitudes of students from classrooms with teachers rated 1, 4, or 5. There were not significant differences among the results of teachers rated 1, 4, or 5.

Discussion

Students' perceptions and attitudes and expert ratings of constructivist science teaching have marginal external validity based on the results of this study. The fundamental assumptions that the constructivist approach should be apparent to students and experts are sound, but the complexity and noise involved in these perceptions and judgments were not fully addressed by this study. An earlier study revealed some degree of alignment among teachers' perceptions of their teaching (use of children's ideas, use of relevant applications, and use of print resources), students' perceptions of and attitudes toward their teachers' teaching, and experts' ratings of teachers' teaching (Yore, et al., 1998). Post hoc correlations of the earlier teachers' perceptions with the students' perceptions and attitudes and the expert ratings from this study for teachers common to both studies revealed supportive associations between students' perceptions and attitudes and teachers' perceptions of using children's ideas and using print resources, and between expert ratings and the same teachers' perceptions as anticipated. These reasonable alignments among what teachers reported occurring in their classrooms and what students and experts perceived happening in the same classrooms regarding the use of children's ideas and the use of literature in science support the construct and substantive validity of students' perceptions and attitudes and experts' ratings as measures of constructivist teaching. Unfortunately, the results of the current study only mildly support the external validity of these measures.

Further refinements of the perceptions and attitudes survey and the ratings rubric are needed. The use of elementary students' (K-6) perceptions of teaching and learning is a relatively untested approach. The perceptions and attitudes survey has been simplified and new data are being collected for the Science PALs project. It appears that the expert rating rubrics have potential for identifying the top and bottom groups of teachers, but the middle group appears to be composed of teachers in transition. These teachers are trying to implement innovative teaching strategies with little success, while the teachers rated low appear to be utilizing traditional strategy with more effectiveness. Further analyses of these data in which only teachers that received the exact same rating for two experts (science supervisor and field coordinator) may reveal whether the assessment noise is caused by the reliabilities of the instruments or the conceptual design and framework of the instruments.

Much of what is considered constructivist teaching is commonplace in most learner-centered, problem-focused primary classrooms. Primary teachers have long assessed students' interests, cognitive abilities, and physical-social development as a basis for their instructional planning, resource selection, and teaching. Frequently, this is referred to as developmentally appropriate teaching. The Science PALs project was designed to utilize developmentally appropriate strategies in teaching science across the elementary school (K -6). This resulted in uniquely different problems dealing with content-pedagogical knowledge. First, it involved getting teachers who utilized developmentally appropriate pedagogy to develop stronger science content knowledge backgrounds so they could use these strategies in teaching science. Addressing children's misconceptions related to specified science modules provided the problem-centered focus for these professional development activities in which groups of teachers worked with a content expert (faculty members, project staff, or secondary school science teacher) to identify typical misconceptions, activities to challenge those misconceptions, and the scientific conceptions. Second, it involved getting teachers with strong science content knowledge backgrounds to develop developmentally appropriate pedagogy so they could facilitate science learning in a constructivist fashion. Using children's literature as a springboard to science served as the problem-centered focus for the professional development activities in which groups of teachers identified stories that could be used as home science activities and as challenge activities for classroom science instruction. Thirdly, it involved working with teachers who had neither strong developmentally appropriate pedagogy nor science content knowledge backgrounds. It is likely this third set of teachers was trapped in transition (the middle categories: CR = 2, ICR = 2, SPR = 2, 3, & 4). These teachers have neither a full grasp of effective constructivist strategies nor the traditional teacher-directed strategies to use. Experts likely noted the positive change toward the desired image while students perceived the uncertainty of the partial transition.

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Table 1: Philosophical, Psychological, Epistemic, and Pedagogical Features of Information Processing, Interactive-Constructivist, Social Constructivist, and Radical Constructivist Approaches (Yore & Shymansky, 1997).

Feature	**Information Processing**	**Interactive-Constructivist**	**Social Constructivist**	**Radical Constructivist**
Worldview	Mechanistic	Hybrid	Contextualistic	Organistic
Epistemic View of Science	Absolutist (traditional) Nature as Judge	Evaluative (modern) Nature as Judge	Evaluative (postmodern) Social Agreement as Judge	Relativist (postmodern) Self as Judge
Locus of Mental Activity	Private	Public and Private	Public	Private
Locus of Control/Structure	Teacher	Shared: Teacher and Individuals	Group	Individual
Discourse	One-Way: Teacher to Student	Two-Way: Negotiations to Surface Alternatives and to Clarify	Two-Way: Negotiations Leading to Consensus	One-Way: Individual to Self (inner speech)

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Table 2: Internal Consistencies of and Number of Items in the Likert Item Factors used to Assess Students' Perceptions and Attitudes (1996 data, 1997 data).

Scale and Factors	**Grade-Level Groupings**					
	1-2		**3-4**		**5-6**	
	1996 (N=831)	**1997 (N=299)**	**1996 (N=722)**	**1997 (N=456)**	**1996 (N=999)**	**1997 (N=560)**
Perceptions of Science Teaching						
Constructivist Approach	0.67(8)	0.69(8)	0.81(21)	0.79(21)	0.85(17)	0.87(17)
Parental Interest	0.70(6)	0.69(6)	0.68(5)	0.61(5)	0.72(7)	0.70(7)
Use of Literature in Science	0.52(3)	0.45(3)	0.49(3)	0.40(3)	0.61(5)	0.59(5)
Attitudes toward Science Learning						
Attitude toward School Science	0.58(6)	0.73(6)	0.74(5)	0.74(5)	0.81(21)	0.80(21)
Careers in Science	0.68(4)	0.68(4)	0.72(3)	0.69(3)	0.79(4)	0.73(4)

Table 3: Descriptive Statistics (Mean and Standard Error) of Students' Perceptions and Attitudes from Teachers' Classrooms with Different Constructivist Ratings (CR)

Perceptions and Attitudes	**Expert Ratings**		
	1	**2**	**3**
Students' Perceptions of Science Teaching	2.42, 0.03	2.41, 0.03	2.39, 0.02
Constructivist Approach	2.77, 0.03	2.80, 0.04	2.72, 0.03
Parental Interest	2.21, 0.04	2.17, 0.04	2.16, 0.03
Use of Literature in Science	2.25, 0.03	2.23, 0.04	2.28, 0.02
Students' Attitudes toward Science Learning	2.28, 0.04	2.20,0.05	2.31, 0.03
Attitude toward School Science	2.39, 0.03	2.28, 0.04	2.40, 0.02
Career in Science	2.16, 0.05	2.12, 0.06	2.21, 0.04

Table 4: Descriptive Statistics (Mean and Standard Error) of Students' Perceptions and Attitudes from Teachers' Classrooms with Different Interactive-Constructivist Ratings (ICR)

Perceptions and Attitudes	**Expert Ratings**		
	1	**2**	**3**
Students' Perceptions of Science Teaching	2.36, 0.02	2.32, 0.03	2.38, 0.02
Constructivist Approach	2.72, 0.03	2.69, 0.04	2.74, 0.03
Parental Interest	2.19, 0.03	2.09, 0.03	2.18. 0.03
Use of Literature in Science	2.20, 0.03	2.26, 0.04	2.31, 0.03
Students' Attitudes toward Science Learning	2.21. 0.03	2.13, 0.03	2.26, 0.03
Attitude toward School Science	2.35, 0.03	2.28, 0.06	2.38, 0.03
Career in Science	2.08, 0.04	1.98, 0.05	2.16, 0.04

Table 5: Descriptive Statistics (Mean and Standard Error) of Students' Perceptions and Attitudes from Teachers' Classrooms with Different Science PALs Ratings (SPR)

Perceptions and Attitudes	**Expert Ratings**			
	1	**2-3**	**4**	**5**
Students' Perceptions of Science Teaching	2.37, 0.02	2.31, 0.03	2.37, 0.03	2.35, 0.02
Constructivist Approach	2.74, 0.03	2.73, 0.04	2.70, 0.04	2.71, 0.03
Parental Interest	2.22, 0.04	2.11, 0.04	2.20, 0.05	2.15, 0.03
Use of Literature in Science	2.22, 0.04	2.21, 0.04	2.30, 0.05	2.29, 0.03
Students' Attitudes toward Science Learning	2.24, 0.04	2.11, 0.04	2.26, 0.05	2.27, 0.03
Attitude toward School Science	2.38, 0.04	2.26, 0.04	2.40, 0.05	2.39, 0.03
Career in Science	2.09, 0.04	1.96, 0.05	2.13, 0.04	2.14, 0.03

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