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Teachers' instructional perspectives and use of educational software

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Abstract

It has been argued that technology will promote the use of constructivist approaches to teaching and learning advocated by the current reform movement. Yet computer technology, in and of itself, does not embody a single pedagogical orientation. Different types of software can be used to address different educational goals. This article examines relationships between teachers' instructional perspectives and their use of technology in instruction. Findings indicate that views about effective computer-based pedagogy are related to the types of software teachers report using with their students. Addressing these perspectives about effective instruction is necessary if computers are to reach their educational potential.

Keywords: Instructional technology; Teacher perspectives; Constructivist approaches; Transmission approaches

1. Introduction

For almost 20 years, research has documented the influence of teachers' beliefs on their instructional practice (Clark & Peterson, 1986; Fang, 1996; Gomez & Stoddart, 1991; Nettle, 1998; Pajares, 1992; Richardson, Anders, Tidwell, & Lloyd, 1991; Stoddart, 1991; Tabachnick & Zeichner, 1984; Vacc & Bright, 1999; Zeichner, Tabachnick, & Densmore, 1987). These studies demonstrate that personal belief systems exert a powerful influence on what teachers learn from reform initiatives and staff development programs, on their curricular decision-making, and on the instructional practices they use in their classrooms.

This research, however, has had little impact on educational reform efforts (Czerniak & Lumpe, 1996). Policy makers still tend to operate as if educational change is a unidirectional process. They assume teachers will accept and implement curriculum and instructional methods mandated from the top down. This is often not the case. A large body of research has demonstrated that many educational reform initiatives failed because they had little impact on teachers' beliefs or practices (Cohen & Ball, 1990; Elmore, 1987; McLaughlin, 1989).

Nowhere is this problem more apparent than in the introduction of educational technology into the public schools. Across the United States, hundreds of millions of dollars have been invested in

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installing computer and telecommunications systems into K–12 schools (West, 1996). The assumption has been that providing technology infrastructure will change teachers' practice (David, 1991, 1994; Sheingold, 1991). In particular, it has been argued that technology can support the use of constructivist approaches to teaching and learning advocated by the current reform movement (Bork, 1992; Dwyer, Ringstaff, & Sandholtz, 1991; Hawkins & Collins, 1992; Linn, 1998; Rakes, 1996; Sandholtz, Ringstaff, & Dwyer, 1997; Savery & Duffy, 1995; Scardamalia & Bereiter, 1996). Although instructional technology *can* be used to support student-centered inquiry-based learning, simply installing computers in schools has done little to change the didactic teaching methods that constitute the prevalent instructional approach in US schools (Cohen, 1990; Cradler, 1994; Cummins, 1996; Goodlad, 1993; Office of Technology Assessment, 1995; Stoddart & Niederhauser, 1993; Van Dusen & Worthen, 1992, 1995). Computer use in K-12 education has primarily involved drill and practice for reading and mathematics skill development and basic word processing (Becker, 1991; Maddux, Johnson, & Willis, 1992; OTA, 1988, 1995).

It is not surprising that computer use has been incorporated into traditional practices. Computer technology, in itself, does not embody a student-centered instructional paradigm. It includes a spectrum of approaches to teaching and learning based on various traditional and innovative instructional theories (Stoddart & Niederhauser, 1993). The literature on how teachers' beliefs shape the implementation of school reform initiatives indicates that teachers will tend to use technology in ways that are consistent with their personal perspectives about curriculum and instructional practice (Cohen, 1987; Cuban, 1986). In 1986, Clark and Peterson cautioned, "Teachers' belief systems can be ignored only at the innovator's peril" (p. 291). Curriculum reform, in technology or any other field, is unlikely to be successful unless we understand how teachers' beliefs influence the implementation of the innovation (Czerniak & Lumpe, 1996).

In this paper, we explore the relationships among teachers' epistemological and pedagogical perspectives and their use of educational software. We examined over 1000 K-6 teachers' perspectives about effective instructional uses of computers and the pedagogical nature of the software they used with students. The context for the study was a statewide educational technology initiative in which funding was provided for districts and schools to purchase technology for instructional purposes. In accordance with the state's site-based management policy, teachers were involved in selecting the types of computer software they would use in their classrooms.

1.1. Teacher beliefs and instructional practice

Teachers bring an established structure of knowledge and beliefs about teaching and learning to the instructional change process which forms an "intuitive screen" through which professional development and classroom teaching reforms are interpreted (Buchanan, Burts, Bidner, White, & Charlesworth, 1998; Clark & Peterson, 1986; Fang, 1996; Johnson, 1992; Posner, Strike, Hewson, & Gertzog, 1982; Richardson et al., 1991; Zeichner et al., 1987). Prior research in several subject areas has demonstrated that teachers tended to adopt new classroom practices based on whether the assumptions inherent in the new programs were consistent with their personal epistomological beliefs (Richardson et al., 1991). In particular, teachers who held more traditional beliefs about teaching and learning tended to use didactic instructional methods while teachers with more constructivist beliefs tended to use student-centered inquiry based methods (DeFord, 1985; Dwyer et al., 1991; Johnson, 1992; Peterson, Fennema, Carpenter, & Loef, 1989; Yocum, 1996).

For example, Peterson and her colleagues found that elementary school teachers' pedagogical perspectives about teaching mathematics were consistent with their self-reported goals for instruction, their choice of instructional methods and subject-matter content, and their conceptions of the roles of students and teachers (Peterson et al., 1989). This consistency was apparent in the teachers' use of manipulatives. Teachers who were identified as having a cognitive constructivist orientation allowed students to use manipulatives while they worked through problem-solving activities involving addition. The children used the manipulatives to help visualize and represent their counting strategies as they thought through the problems. In contrast, teachers with a more didactic perspective directed their students to use the manipulatives in specific ways. Students were instructed to arrange the manipulative objects in groupings to provide a concrete representation of standard mathematical algorithms. Thus, in classrooms where the teacher had a more constructivist perspective, students used the manipulatives to explore and develop understandings of the mathematical concepts. Students whose teachers had a more didactic perspective were taught to use the objects as a concrete way to represent the teachers' algorithmic model. Both groups of teachers might have claimed they were using reform-oriented methods by including activities with manipulatives, but their predisposition to a particular epistemological and pedagogical perspective had a powerful influence on how the reform was implemented.

Similar findings are reported in studies of language and literacy. Johnson (1992), found that instruction provided by teachers of English as a Second Language (ESL) was consistent with their theoretical orientation. Teachers with a didactic orientation to instruction tended to separate language instruction into discrete listening, speaking, reading and writing skills and used activities that focused on oral production with an emphasis on correct pronunciation. Teachers who espoused constructivist principles focused on helping their students learn to communicate and were more likely to use interactive discourse strategies and cooperative learning. DeFord (1985) found a strong correlation between teachers' classroom practices and their scores on the theoretical orientation to reading profile (TORP) — a multiple-choice measure designed to characterize a teacher's theoretical and pedagogical beliefs about reading as having a phonics, skills, or whole language orientation.

The only major study to examine the relationships among teachers' epistemological beliefs, pedagogical beliefs, and their instructional uses of technology was conducted as a part of an evaluation of the Apple Classrooms of Tomorrow (ACOT) project (Dwyer et al, 1991; Yocum, 1996). The ACOT project provided computers, printers, scanners, laserdiscs, and other hardware as well as hundreds of software titles for selected classrooms across the country. Teachers received extensive technical support and staff development to help them implement constructivist pedagogy using technology. Teachers who were more accepting of constructivist principles were more likely to select open-ended inquiry software over drill and practice software (Dwyer, 1994). Overall, however, the project resulted in little change in participating teachers practice (Yocum, 1996). Dwyer and his colleagues (1991) concluded that even though teachers' in the study were dedicated to the investigation of the potential of modern technology to improve education, they were held in check by personal and institutional habits that characterize traditional didactic instructional methods. Thus, even with the extreme levels of equipment, support, and staff development provided through the ACOT project, teachers' pedagogical perspectives limited how technology was used in the classroom.

Many policy makers assume that technology is an approach to instruction that is "teacher proof" (David, 1991, 1994; Sheingold, 1991). They imply that something inherent in the technology will promote instructional reform. Educational technology, however, is a tool that can be used to support a variety of approaches to instruction. Teachers can select and use educational software, as they select and use other instructional materials, to match their personal instructional philosophies — whether traditional or reform-oriented.

1.2. Instructional approaches and educational technology

Educational software development draws on a variety of instructional approaches. Different theoretical orientations to teaching and learning have shaped the development of a spectrum of educational software packages (Stoddart & Niederhauser, 1993). Instructional software, like other curricular and instructional materials, is based on both didactic and constructivist conceptions of teaching and learning.

Behaviorist theory has been enormously influential in the design of instructional technology and computer software (Dick, 1991; Merrill, 1991). Behaviorism is based on the objectivist view that learning should involve students in mastering and replicating the knowledge and skills transmitted to them in school (Duffy & Jonassen, 1992; Lakoff, 1987). Computer programs based on this paradigm are widely used in traditional classrooms (Maddux & Willis, 1992; OTA, 1988, 1995). Drill and practice-based integrated learning systems (ILS) evolved from Skinner's (1968) mechanical programmed instruction teaching machines. In developing an ILS, instructional designers use the computer as a tool for hierarchically structuring a sequence of activities and managing the stimulus/response/feedback loop that constitutes the behavioral conditioning process. The computer displays a problem for the student (stimulus) who, in turn, responds with an answer (response). The computer then provides feedback to the student regarding whether he or she has provided the "right" answer (reinforcement). Teachers can easily integrate such drill and practice computer activities into their established didactic routines (Bork, 1980; Cole & Griffen, 1987).

The design of instructional software has also been influenced by constructivist theories (diSessa, 1986; Linn, 1998; Papert, 1980, 1993; Sandholtz et al., 1997; Savery & Duffy, 1995; Scardamalia & Bereiter, 1996; Schwartz & Yerushalmy, 1987). Computer software programs based on constructivist principles provide students with the experiences that allow them to discover or re-invent concepts. Students are given access to a variety of open-ended applications that they use to help construct more complex understandings. For example, students may use a computer-generated virtual environment, known as a "microworld," to enhance their learning. Papert (1980) developed some of the original microworld software. He describes his LOGO "Turtle" as a computational "object to think with". Children learn about geometry and logic by "teaching" the Turtle routines that create geometrical figures and perform various functions. This involves planning and error detection and analysis as an ongoing process.

Another constructivist approach involves helping students to use the computer as a tool to collect and organize data, then present what has been learned. The learner acts as an active seeker of information who revises and updates his or her knowledge through the process of gathering new information. The focus of programs that are designed to be used in a more constructivist fashion is not on ensuring students get a single "right" answer, rather it is on helping them develop increasingly complex and thorough understandings.

Pedagogies based on behaviorist and constructivist theoretical orientations represent dramatically different views of teaching and learning and give rise to fundamentally different conceptions of the use of computers in instruction — as a didactic teaching machine or as constructivist thinking and reflecting tools. This study examines whether teachers' perspectives about educational uses of computers can be characterized in terms of didactic or constructivist orientations toward teaching and whether the instructional software they use is consistent with these perspectives.

2. Method

The data reported in this study were collected as a part of the evaluation of a statewide technology initiative assessment. A written survey was used to collect information on teachers' use of educational software and their perspectives about effective instructional uses for computers.

2.1. Data sources

Questionnaires were mailed to all 418 elementary schools in a western state that is widely recognized for leadership in educational technology. Schools in the study represented both rural and urban areas. Six questionnaires and a cover letter were mailed to each school. The cover letter asked principals to distribute questionnaires to two teachers from each of three grade level groupings (K-2, 3–4, 5–6). Completed questionnaires were mailed back to the researchers. A total of 1093 teachers (866 female and 227 male) completed and returned surveys (44% return rate). Included were 350 teachers in the K-2 grade group, 391 teachers in the 3–4 grade group, and 352 teachers in the 5–6 grade group. Respondents ranged from first-year teachers to 40-year veterans with an average of 12.20 years (SD = 7.34) of teaching experience.

2.2. Measures

The questionnaire developed to collect data on teachers' instructional usage of computers included three sections of importance to this study: (a) teacher demographics, (b) teachers' perspectives about effective instructional uses of technology, and (c) the software teachers used for instruction. The teacher demographics section included items on the background of participating teachers. Teachers were asked to list their school and district, gender, number of years teaching, and the amount of time they spent using technology to prepare for instruction.

Items in the teachers' perspectives section of the questionnaire were designed to assess perceptions about effective instructional uses of computers. Previous research indicated that an effective way to examine teachers' pedagogical perspectives was through their agreement with propositional statements that reflect differing theoretical views about the learning process (i.e., DeFord, 1985; Duffy & Metheny, 1979; Muchmore, 1994; Peterson et al., 1989). Researchers who developed scales to examine teachers' instructional perspectives in other content areas have typically created 5–12 items to address each scale or category (see DeFord, 1985; Duffy & Anderson, 1986; Johnson, 1992; Peterson et al., 1989), while others have used as few as two or three items per construct (see Muchmore, 1994; Scott & Hannafin, 1996).

Using guidelines established by Fowler (1995), we developed 18 propositional statements to assess whether teachers believed computers were: (1) *much less effective,* (2) *somewhat less effective,* (3) *the same,* (4) *somewhat more effective,* or (5) *much more effective* than more traditional forms of instruction for accomplishing a variety of instructional goals. Nine items were written to reflect a more didactic view of instruction (e.g., "Providing students with practice in basic skills" and "Reinforcing each right answer") while the remaining nine items were written to reflect a more constructivist orientation to instruction (e.g., "Developing higher-order thinking skills" and "Helping students to construct their own representations of concepts"). Teachers used the five-point Likert scale to indicate their instructional perspectives regarding effective instructional uses for computers.

Teacher perception questionnaire items were reviewed by seven practicing elementary school teachers to determine the face validity of the questions. Several items were revised slightly to address issues raised by the teachers concerning phrasing and clarity. The questionnaire items were then reviewed by four educational psychologists who had expertise in learning theory to establish content validity. These reviewers agreed that the two sets of questions were consistent with different theoretical approaches to instruction.

In the third section, teachers were asked to list titles of up to four instructional software programs that they regularly used with their students. They indicated how often students used each title, and the subject area that the software addressed.

3. Results

The results are reported in three sections that represent phases of the analysis. In the first phase, the types of computer software teachers used were categorized using a rubric that reflected didactic and constructivist instructional orientations. Teachers' responses to the propositional questionnaire items were then used to identify and characterize patterns in teachers' perspectives about effective instructional uses of computers. The third phase of analysis was an examination of the relationship between teachers' perspectives and the software they used.

3.1. Teachers' use of instructional software

Categories were developed to reflect the orientation towards learning underlying the software teachers listed. To accomplish this, a comprehensive list of all software that teachers used with their students was compiled and we examined the list to

Table 1
Software categories

Category	Examples
Skill-based transmission software	
Drill-and-practice (DP)	Reader Rabbit, Math Blasters, IBM Math Practice
Keyboarding (KB)	Touchtyping for Beginners, Typing Tutor
Open-ended constructivist software	
Interactive/Educational Games (INT/GAME)	Carmen San Diego; Measurement, Time and Money; Oregon Trail
Exploratory (EXPL)	Geometric Supposer, Logo, Math Exploration Toolkit
Productivity/Presentation Tools (TOOL)	Wordperfect, MS Word, Lotus 123, Hypercard, Powerpoint, Netscape

identify unfamiliar titles. Any program that was not familiar to both researchers was reviewed. When the software review step was complete, we identified features that could be used to categorize the software titles based on the orientation toward learning underlying the design and use of the programs. For example, drill-and-practice software draws on a didactic orientation toward learning, while programs like Logo or HyperCard were designed to support more constructivist uses.

3.1.1. *Software categories*

An initial set of categories was established and each of the software titles was independently assigned to one of the categories. Interrater reliability was 92%. We then examined the two independently categorized lists, identified discrepancies, and resolved differences through discussion. All software titles were coded based on the categories identified in Table 1. Software that draws on the didactic tradition is included in the Skill-based Transmission category and software that can be used in more constructivist ways in the Open-ended Constructivist category.

3.1.1.1. Skill-based transmission software Two types of traditional skill-based transmission software were identified: Drill-and-Practice (DP) and Keyboarding (KB). Software included in these categories draw on objectivist behavioral principles of learning aimed at helping students internalize basic facts and skills (Stoddart & Niederhauser, 1993). The software is used to introduce content in small hierarchical steps, present stimuli, provide immediate feedback and reinforcement, allow for repetition and practice, and monitor student progress.

The core of these types of computer programs is the stimulus–response feedback loop. The student is prompted by the computer, enters an answer or performs a task, and the computer indicates whether the response was right or wrong. In order for this process to occur, the computer must be programmed to compare student responses with a predetermined "right" answer. Thus, right answers are seen as absolute and what will count as a correct response is pre-programmed into the software. The software controls the learning activity including determining what information is to be presented, sequencing activities, stimulus presentation and response methods, determining the accuracy of responses, and providing feedback. This highly structured form of instruction can be effective for ensuring that students develop mastery of defined content and automaticity of skills. Teachers in this study reported using a variety of drill and practice programs including: *Reader Rabbit* (The Learning Company, 1991) which promotes letter recognition and letter/sound correspondence; *Math Practice* (IBM, 1987) which drills students on basic math skills; and *Touchtyping for Beginners* (IBM, 1991) which trains students to use typing techniques such as correct finger placements and keystrokes.

3.1.1.2. Open-ended constructivist software Three types of open-ended constructivist software were identified: Interactive and Educational Game

(INT/GAME), Exploratory (EXPL), and Tool (TOOL) programs. These programs provide a "microworld" environment, and/or productivity tools to support the learning process. Software that is used in constructivist ways provides a flexible learner-directed workspace. The computer is a tool for learning, rather than a teaching machine.

INT/GAME software focuses learning on solving problems in a structured context. Students are presented with a complex problem and provided with information and tools to assist them in finding a solution to the problem. There are often multiple ways to solve the problems, although certain tasks must be performed and/or information found in order to complete the activities and win the game. For example, in *Where in the World is Carmen San Diego* (Broderbund, 1996), students role play a detective in a virtual worldwide search for a crime suspect to seek information and use logic to solve the "case" as they learn history and geography.

EXPL programs are content-specific applications (sometimes called microworlds) that support the learner in discovery and guided discovery "playspaces," or offer constrained simulations of real-world phenomena (Rieber, 1993). EXPL programs do not teach a preset body of knowledge so the learner determines the questions and activities to be pursued, often with input from teachers, activity guides, and/or peers. Responsibility for evaluating learning is also external to the program. Participants decide how to use the software, and evaluate what has been learned relative to their own goals. Some teachers in the study reported using a series of exploratory programs called *Geometric Supposers* (Schwartz & Yerushalmy, 1987). Geometric Supposers are computer-based tools that support learners as they manipulate variables to explore the properties of geometric objects.

TOOL programs are productivity software that support learners as they find, organize, manipulate and present information. The instructional value of these programs lies in how they are used, rather than being inherent in the design of the programs. Students can use the Internet to access information, a spreadsheet to organize data collected in experiments, a graphics package to prepare diagrams and charts, a word processor to organize and present textual information, and a multimedia presentation program to prepare and present a final report. Students can use TOOL software to engage in independent and group projects and develop a representation of their understanding of a process or body of knowledge.

3.1.2. *Using educational software*

This study relies on teachers' self-report data of their perspectives and practices. Unlike most self-report of practice studies, however, the computer program rather than the teacher structured the teacher-learner interaction. By examining the programs teachers reported using, we were able to infer the kinds of teaching and learning experiences students encountered when using the software

The *Waterford Mental Math Games* (Waterford Institute, 1992) program was one of the programs teachers reported using for drill and practice in mathematics. When students used the program, they completed an electronic mathematics work sheet containing basic addition problems (e.g., $14 + 9 = \_$). Students worked as fast as they could because they knew that they were being scored on speed as well as accuracy. When they completed the worksheet, the computer gave them a score that was represented in two bar graphs — one for accuracy and another for speed. If they met the criterion set by the teacher a cartoon appeared, e.g., in one case a fairground scene with a cartoon character testing his strength by hitting a block with a hammer to ring a bell. If the student did not meet the criterion, she/he was given another screen of problems to complete. If she/he failed again, another problem set was presented. Students were allowed three attempts. Those who failed were rerouted to a simpler exercise by the computer. Those who reached the preset mastery criterion chose a brief game to play against a peer. *Mental Math Games* is a drill and practice program used to promote the memorization of math facts. Students were not provided with opportunities to explore concepts or develop their own representations. They simply acted as respondents — reacting to reinforcement of right or wrong answers.

Contrast the learning experience described above with a more open-ended computer-based math program, *Exploring Measurement, Time and*

Money (IBM, 1989). This program provided students with a variety of ways to interact with mathematical concepts. For example, a section called *Measure It* contained five types of activities: (1) In *Explore*, students used different types of measuring tools (a string of paper clips, an inch ruler, a half inch ruler) to measure different objects (i.e., crayon, comb, hammer, spoon, etc.) on the computer screen; (2) In *Measure*, students used the tools from Explore to complete measurement problems; (3) In *Follow the Clue*, students compared the sizes of objects by estimating or using the measurement tools; (4) In *Read the Graph*, the computer created simple bar graphs of the size of objects students encountered in other activities; and (5) in *Graphmaker*, students entered their own data to create simple spreadsheets and graphs. Students interacted with the program by moving objects around on the screen (e.g., moving the spoon next to the measuring tape to see how long it was).

In *Exploring Measurement, Time and Money*, the computer program provided an environment and experiences that allowed students to construct and develop their own understanding of a concept. The program determined the topics that were addressed but there was flexibility and interactivity in how the learner explored the concepts. The responsibility for constructing meaning resided with the student. This is essentially a guided exploration or "hands on learning" approach provided through computer simulation.

These examples suggest that teachers' selection of different types of instructional software can lead to very different learning experiences for students. In the next step of the analysis we examined the types of software teachers reported using differentiated by grade level and gender.

3.1.3. *Teachers' software use*

Individual teachers were assigned to groups based on the types of software they used with their students. The Skills-based group ($n = 401$) listed only DP and/or KB software. The Open-ended group ($n = 161$) listed only INT/GAMES, EXPL, and/or TOOLS software. The Combined Group ($n = 531$) listed a combination of skills-based and open-ended software. The overall results indicate that the majority (85%) of teachers participating in

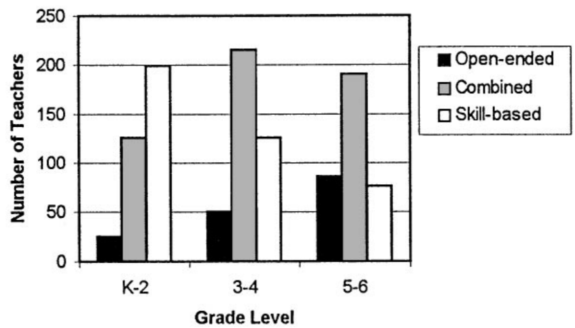

Fig. 1. Types of software teachers used across grade levels.

the study used skill-based software for instruction, either solely (36%) or at least part of the time. A large number of these teachers (49%), however, were in the Combined group — that is they included the use of open-ended programs with their use of drill and practice software. Very few teachers (15%) relied only on constructivist-oriented software.

A Kruskall–Wallis Analysis of Variance by ranks (K–W ANOVA) was used to examine the makeup of the software groupings based on grade level, gender, and years of teaching experience. There were significant differences in software use between teachers at different grade levels (H (2, $N = 1093$) $= 107.72$, $p < 0.001$). As Fig. 1 shows, K-2 teachers were more likely to use skill-based software than were teachers at the higher grade levels. The majority of 3–6 grade teachers used both types of software. In contrast, teachers in the 5–6 grade group were more likely to use open-ended software with their students. Thus, the number of teachers who used only skill-based software declined steadily as grade level increased, while open-ended uses tended to increase with grade level.

There were also differences in software use between male and female teachers (H (1, $N = 1093$) $= 16.19$, $p < 0.001$). As Fig. 2 shows, a greater proportion of female teachers reported using skill-based software (39%) or a combination of skill-based and open-ended software (48%). Only 13% reported using solely open-ended software. Most male teachers used a combined

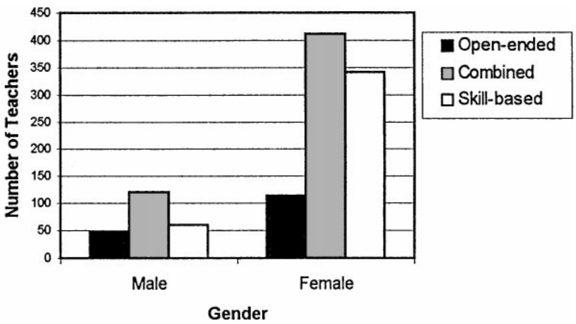

Fig. 2. Types of software teachers used across genders.

approach (53%), while there was more of a balance between skill-based software users (26%) and open-ended software users (21%).

An interesting shift emerges when gender differences are examined within grade level groupings (Fig. 3). The pattern for 3–4 teachers is consistent with the overall gender analysis. Most 3–4 teachers used a combined approach (male = 52%; female = 56%), followed by teachers who used only skill-based software (male = 30%; female = 33%), and those who used only open-ended software (male = 18%; female = 11%). K–2 teachers made very limited use of open-ended software (male = 10%; female = 7%), followed by a larger number of teachers who used a combination of software (male = 43%; female = 36%), and the largest group who used only skill-based software (male = 47%; female = 57%). At the 5–6 level, we found a more balanced pattern with most teachers using a combined approach (male = 56%; female = 53%), followed by the group who used only open-ended software (male = 25%; female = 24%), and a slightly smaller group who used only skill-based software (male = 19%; female = 23%). Within grade level groupings the pattern of results for male and female teachers tends to look fairly similar; however, at all levels proportionally more female teachers used only skill-based software than did their male counterparts and male teachers tended to use open-ended software slightly more frequently than did female teachers.

Surprisingly, years of teaching experience did not significantly differentiate the types of software used ($H(1, N = 1093) = 1.91$, $p > 0.16$). We had anticipated that teachers who were newer to the profession and had recently received their preservice training would have had a more constructivist perspective — but that was not the case. Software use was spread evenly across teachers of all experience levels.

3.2. Teachers' perspectives about computer use

Phase II analysis involved characterizing teachers' perspectives about effective computer use.

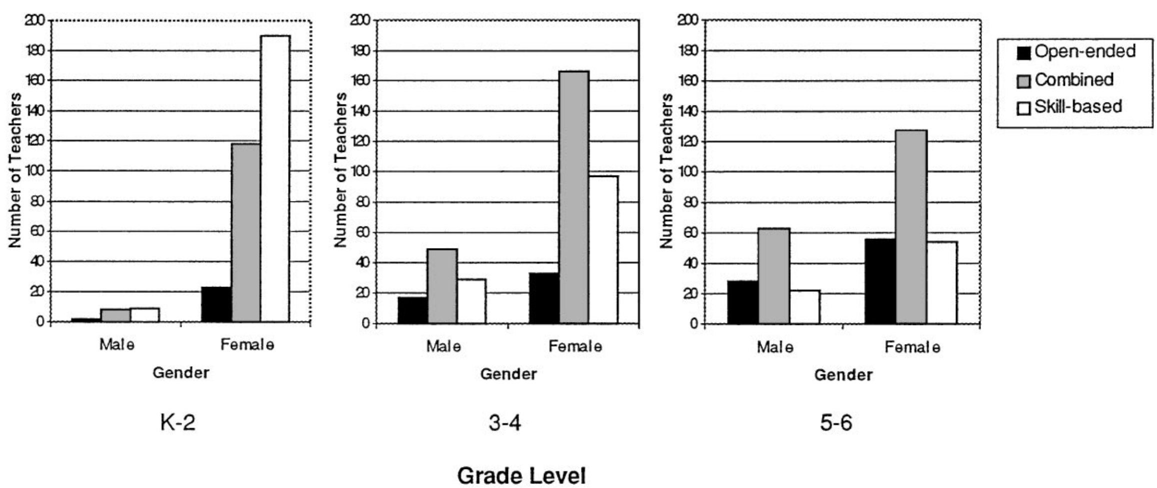

Fig. 3. Types of software teachers used across grade levels and genders.

Table 2
Identifying items for factor labels[a]

Factor 1: Learner-centered Construction of Knowledge
Item 17: Helping students to construct their own representations of concepts (0.82)
Item 16: Allowing students to analyze data, draw inferences and generate their own problem solutions (0.81)
Item 14: Providing experiences that enable students to discover concepts for themselves (0.76)
Item 10: Developing higher-order thinking skills (0.74)
Item 12: Promoting student creativity (0.73)
Factor 2: Computer-directed Transmission of Knowledge
Item 18: Providing students with practice in basic skills (0.71)
Item 13: Providing drill-and-practice in the content required by the core curriculum (0.71)
Item 7: Making sure students get the right answer (0.65)
Item 8: Reinforcing each right answer (0.64)
Item 11: Remediating student learning deficits (0.56)

[a] Eigenvalues in parentheses

The analysis of teachers' perspectives about instructional uses of computers was based on their ratings of the effectiveness of computer-based instruction for a range of traditional and constructivist instructional goals. Our analysis was guided by Richardson (1994), who drew on Hook and Rosenshine's (1979) review of the literature to conclude that responses from paper-and-pencil teacher beliefs questionnaire were more reliable when grouped into more global dimensions or general styles, rather than specific perspectives and behaviors. We used Principal Component Analysis to combine questionnaire items and provide a rich view of a single attribute (Litwin, 1995).

The 18 instructional perspective questionnaire items were entered into a Principal Component Analysis to determine whether individual items were related to each other in meaningful ways. The initial composition of the unadjusted correlation matrix extracted three factors with eigenvalues greater than 1, which accounted for 55.1% of the total variance in the matrix. Examination of the scree plot of the factors indicated that two of the factors were viable. These two factors were retained and the factor matrix was rotated using the varimax method. The two factor orthogonal solution was theoretically meaningful and supported the decision to retain only two factors. These factors accounted for 49.3% of the total variance in the matrix (Factor 1 = 39.4%; Factor 2 = 9.9%).

The items most influential in the make-up of each factor were identified and the factors were labeled. The first factor was named *learner-centered construction of knowledge* and the second factor *computer-directed transmission of knowledge* (see Table 2).

The fact that two factors emerged which were consistent with the teachers' instructional perspectives we were trying to differentiate is a good indication of the ecological validity of the questionnaire. That is, questionnaire items appeared to measure what we had intended. The internal consistency of the questionnaire was examined through the use of Cronbach's coefficient alpha. This statistic provides an indication of how well the different items measure the same issue (Litwin, 1995). Homogeneity of scale of 0.70 or higher is considered good reliability. The teachers' perspectives questionnaire had an overall Cronbach's coefficient Alpha of 0.91 with a 0.89 coefficient for learner-centered factor items and a 0.82 coefficient for computer-directed factor items. Thus, there is strong conceptual and statistical support for the integrity of the questionnaire.

A learner-centered and a computer-directed factor score was computed for each teacher. A high score on the learner-centered factor was an indication that the teacher viewed computers as tools to support students as they constructed knowledge. A high score on the computer-directed factor reflected the perspective that computers were most effective as a teaching machine for providing students with drill-and-practice in basic skills. Both learner-centered and computer-directed factor scores were used to provide a more comprehensive measure of the complexity of teachers' perspectives. Some teachers had a high score on one factor and a low score on the other factor, reflecting a single and consistent orientation. Other teachers had high scores on both factors (computer-based instruction is always more effective than traditional instruction), or low scores on both factors (traditional instruction is always more effective than computer-based instruction). Factor scores were used as dependent measures in Phase III analyses.

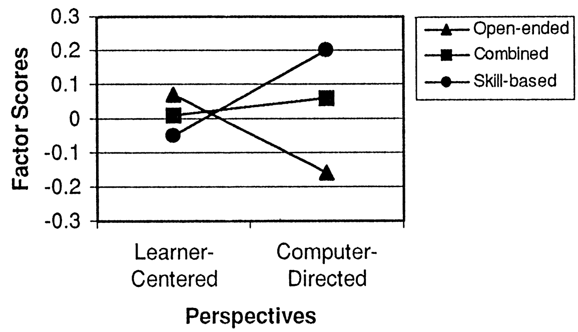

Fig. 4. Relationship between pedagogical orientation and software used.

3.3. *The relationships among teachers' instructional perspectives and their software use*

The third phase of analysis examined the relationships among the teachers' pedagogical orientation towards instructional uses of computers and the types of software they used with students. A $3\times3\times2\times2$ mixed analysis of variance (ANOVA) was conducted with grade level (K-2 vs. 3–4 vs. 5–6), software type (open-ended vs. combined vs. skill-based), and years teaching (1–11 vs. 12–40 years) as between subject factors and pedagogical orientation (learner-centered vs. computer-directed) as a within subject factor. The two factor scores (learner-centered construction of knowledge and computer-directed transmission of knowledge) were used as dependent measures. Unfortunately, there were not enough male teachers in the K–2 group to include gender as a factor in these analyses.

The interaction between software type and pedagogical orientation was statistically significant ($F(2,\ 1075) = 6.65$, $MSE = 0.97$ $p < 0.001$). As Fig. 4 shows, teachers who used only open-ended software had moderate learner-centered factor scores ($M = 0.07$, $SD = 0.98$) and low computer-directed factor scores ($M = -0.16$, $SD = 1.00$). Teachers who used both types of software had moderate scores on both factors (learner-centered factor $M = 0.01$, $SD = 0.96$; computer-directed factor $M = 0.06$, $SD = 0.99$). Teachers who used only skill-based software had moderate scores on the learner-centered factor ($M = -0.05$, $SD = 1.02$) and high scores on the computer-directed factor ($M = 0.20$, $SD = 0.87$).

These results indicate a fairly consistent relationship between teachers' perspectives about the instructional uses of computers and the types of software they used with students. Teachers who only used open-ended software had the strongest learner-centered perspectives and the weakest computer-directed perspectives. Teachers who used only skill-based software had the strongest computer-directed and lowest learner-centered perspectives. Teachers who used both types of software fell between the other two groups on both scales. The greatest differences were found between open-ended and skill-based users on the computer-directed factor.

The grade level by software type by pedagogical orientation interaction also reached significance ($F(4,\ 1075) = 2.51$, $MSE = 0.97$ $p < 0.05$). As Fig. 5 shows, K-2 teachers who used only open-ended software or a combination of both types of software had very low scores on the computer-directed factor ($M = -0.22$, $SD = 1.03$; $M = -0.14$, $SD = 1.01$, respectively) and higher scores on the learner-centered factor ($M = 0.07$, $SD = 1.02$; $M = 0.14$, $SD = 0.88$, respectively). The pattern was reversed for K–2 teachers who used only skill-based software — these teachers had very high scores on the computer-directed factor ($M = 0.25$, $SD = 0.67$). and lower scores on the learner-centered factor ($M = 0.02, SD = 0.97$). The largest variation in the K–2 group was on the

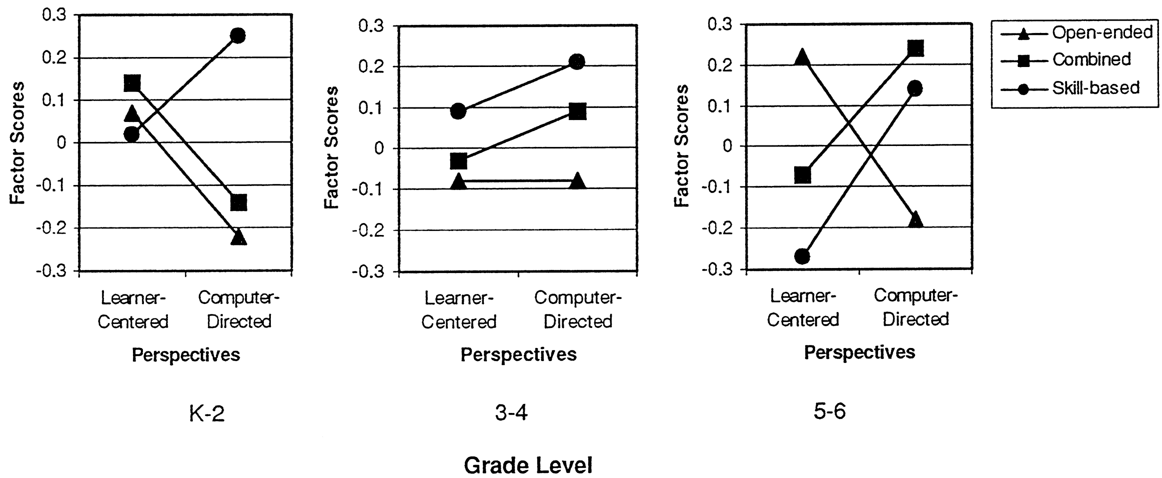

Fig. 5. Relationship between pedagogical orientation and software used across grade levels.

computer-directed factor. The skill-based group was very favorable toward computer-directed uses while both the combined and open-ended groups had negative views on the effectiveness of computer-directed instruction.

Teachers in the 3–4 grade group who used only open-ended software had moderate scores on both the learner-centered factor ($M = -0.08$, $\mathrm{SD} = 1.01$) and the computer-directed factor ($M = -0.08, \mathrm{SD} = 0.97$). Teachers in the combined group had moderate learner-centered factor scores ($M = -0.03, \mathrm{SD} = 1.03$) and fairly high computer-directed factor scores ($M = 0.09, \mathrm{SD} = 0.99$). Teachers who used only skill-based software had fairly high learner-centered factor scores ($M = 0.09, \mathrm{SD} = 1.03$) and high computer-directed factor scores ($M = 0.21, \mathrm{SD} = 0.94$). These results indicate that teachers in the 3–4 group who used only open-ended software had rather negative views about the instructional effectiveness of computers, while both the combined and skill-based groups were more favorable towards computer-directed uses.

The pattern of the 5–6 grade teachers was essentially the reverse of the pattern identified for the K–2 grade group. Teachers who used a combination of both types of software or only skill-based software had higher scores on the computer-directed factor ($M = 0.24, \mathrm{SD} = 0.96$; $M = 0.14, \mathrm{SD} = 1.00$, respectively) and lower scores on the learner-centered factor ($M = -0.07, \mathrm{SD} = 0.98; M = -0.27, \mathrm{SD} = 1.08$, respectively). Teachers who only used open-ended software had high learner-centered scores ($M = 0.22, \mathrm{SD} = 0.90$) and low computer-directed scores ($M = -0.18, \mathrm{SD} = 0.98$). The largest variation in the 5–6 grade group was on the learner-centered factor, with the open-ended group being very favorable and the combined and skill-based group being unfavorable towards this perspective. No other results in this analysis reached significance.

The overall pattern indicates that as grade level (K–6) increased, teachers who used a combination of both types of software became more favorable towards computer-directed approaches to instruction and less favorable toward learner-centered uses. At the K–2 grade level, perspectives of teachers in the combined group were similar to those of teachers who used only open-ended software — they favored learner-centered uses over computer-directed approaches. At the 3–4 grade level, combined group users looked more like skill-based software users and tended to view computer-directed approaches as slightly more effective than the learner-centered approaches. This shift in the combined group towards computer-directed approaches mirrors the skill-based users group as the strength of their commitment to a single approach is increased in the 5–6 grade group. Thus, combined group teachers were more learner-centered in their orientation in the early grades but shifted towards a more computer-directed orientation in the higher grades.

In addition, K–2 teachers from all three groupings (open-ended, combined, and skill-based) held moderately positive learner-centered perspectives, but much more differentiated computer-directed perspectives — they were strongly for or against drill and practice uses. Teachers in the 5–6 group, however, were highly differentiated on both factors — if 5–6 teachers were positive toward learner-centered uses, they were negative toward computer-directed uses, and if they were negative toward learner-centered uses, they were positive toward computer-directed uses. Thus, teachers in the 5–6 group tended to have more differentiated and dogmatic perspectives about effective ways to teach with computers.

4. Discussion

The purpose of this study was to examine the relationships among teachers' perspectives about effective instructional uses of computers and the types of software they used. Although technology is often viewed as an instructional methodology that is value free and teacher-proof (David, 1991, 1994; Sheingold, 1991), the design of educational software is based on both traditional didactic and constructivist approaches to teaching and learning (Stoddart & Niederhauser, 1993). Teachers can select software, as they select other curricula and instructional methods, to fit with their existing pedagogical perspectives. These perspectives can have a powerful influence on how computers get integrated into instructional practices.

In this study, teachers' software use was categorized on the basis of the instructional theory inherent in the design and use of the program. Two overarching types of instructional software were identified: Skill-based software that embodied a traditional transmission approach to instruction, and open-ended software that embodied a constructivist learner-centered approach. Teachers' perspectives about using computers for instruction were assessed on the basis of their agreement with propositional statements that reflected didactic and constuctivist views of the teaching–learning process. Teachers' scores on the two pedagogical orientation factors (learner-centered construction of knowledge and computer-directed transmission of knowledge) were analyzed in relation to their software use. The results indicated that students were using skill-based software alone or in combination with open-ended software in the majority of classrooms (85%). Very few teachers reported using only student-centered open-ended software. This finding is consistent with research that indicates didactic uses of computers and skill-based software continue to be pervasive in the schools (Cole & Griffen, 1987; Maddux & Willis, 1992; OTA, 1995).

We also identified a consistent relationship between teachers' perspectives about the instructional uses of computers and the types of software they used with their students. Teachers who only used open-ended software had a strong learner-centered orientation and a weak computer-directed orientation, while teachers who used only skill-based software had the strongest computer-directed and lowest learner-centered orientations as determined by factor scores. Teachers who used both types of software fell between the other two groups on both instructional orientation scales.

This pattern, however, was not stable across grade levels. Results indicated that K–2 teachers favored the use of skill-based software over open-ended to a greater degree than did the 3–6 grade teachers. This may be due to teachers' emphasis on ensuring students developed foundational skills in early grades and the wide availability of skill-based software designed for young children. In addition, K–2 teachers who used only skill-based software had the highest score of all groups on the computer-directed factor — indicating consistency between their instructional orientations and the nature of the software they used.

The majority of 3–6 grade teachers used both types of software and had fairly favorable views about the effectiveness of both computer-directed and learner-centered uses. Teachers in the 5–6 grade group, however, were more likely to use open-ended software than teachers in the lower grades and those who used only open-ended software had very high learner-centered scores. Thus, the number of teachers who used only skill-based software declined steadily as grade level increased, while combined and open-ended uses tended to increase with grade level.

The most dramatic shift across grade levels occurred in the groups of teachers who used both types of software — the combined group. At the K–2 level these teachers tended to hold perspectives that were similar to teachers who used only open-ended software, that is, they favored learner-centered uses over computer-directed uses. This is consistent with the nurturing, child-centered orientation at early childhood and primary grades discussed previously. However, combined group users looked more like skill-based users at the 3–4 level. They tended to see computer-directed uses as more effective than learner-centered uses, although their scores were fairly moderate and fell between the open-ended and skill-based groups' scores. This shift is accentuated at the 5–6 level. Although the Combined group 5–6 teachers did not view tool-based uses as negatively as did the skill-based group, they rated computer-directed uses very favorably.

Thus, combined group teachers were more learner-centered in their orientation at the earlier grades, but shifted to a more skill-based orientation in the higher grades. This group is particularly interesting because they had access to both types of software and made choices about what types of software to use — presumably based on their beliefs about teaching and learning. Perhaps these teachers were highly sophisticated users who chose different types of software to meet specific educational goals — drill-and-practice software to build skills, and more open-ended software to meet their reform-based instructional goals. Or, combined group teachers may simply have used all of the different types of software that were available to them. They may not have considered how it fit with their pedagogical orientation, but instead used what was present due to various structural and contextual factors. Although beyond the scope of the present study, in-depth interviews with teachers to determine why they chose to use certain types of software would further our understanding of these complex issues.

Since using computers to support their teaching was fairly new to all these teachers, it will be interesting to track the development of their beliefs and use of computers over time. The ACOT research suggests that teachers shift toward more open-ended types of software as their pedagogical beliefs become more constructivist in nature. Monitoring shifts, especially in the combined group, would provide insights into the dynamics of these changes. In addition, further research using classroom observations would allow us to examine whether teachers tend to use the different types of software in ways that are consistent with the characterizations identified in our framework. This would help us understand how teachers integrate instructional uses of computers with other instructional activities.

Teachers' existing beliefs about learning and instruction are clearly important considerations when engaging in instructional reform. The questionnaire developed for this study provides an instrument for examining teachers' orientations toward teaching with computers. This information can provide insights for teacher educators who are interested in promoting instructional reform for pre-service and in-service teachers. Teachers' entering orientations can be identified and activities structured to guide the development of their views on teaching, learning and the role of technology in their practice. The questionnaire might also prove useful in tracking changes in teachers' perspectives and evaluating the effectiveness of professional development activities.

5. Conclusion

It has become increasingly apparent that ignoring teachers' beliefs when implementing instructional change leads to disappointing results (Clark & Peterson, 1986; Richardson et al., 1991). Teachers who are adopting instructional reforms may question the value of teaching with computers when the focus of skill-based software is inconsistent with their pedagogical orientation. To increase the likelihood that computers will be used in ways that are consistent with instructional reforms, professional and pre-service development programs can focus on coupling changes in teachers' conceptions of the teaching and learning process with the availability of appropriate software and training in how to use it with their students. Effective school reform efforts should integrate technology as a key component in the process (David,1991).

Computer technology, in and of itself, does not embody a specific pedagogical orientation. Different types of software can be used to address a range of educational goals. Drill-and-practice and tutorial software can be effective in helping students develop specific skills. Interactive, exploratory and tool software can support teachers as they implement reform-oriented constructivist practices. To date, computers have been primarily used as teaching machines, rather than serving as a catalyst to spur the instructional reform movement. Teachers need assistance in becoming more aware of how computers can be used to help their students meet a range of instructional objectives.

The results of this study indicate that teachers' perspectives about effective computer-based pedagogy are related to the types of software they use with their students. This finding is consistent with other research that shows teachers' pedagogical and epistemological orientations are related to their practices (see Clark & Peterson, 1986; Pajares, 1992; Richardson, 1994; Shavelson, 1983). In light of this, integrating computers into the fabric of US schools will involve much more than simply installing hardware in classrooms and labs. Effective ways to use computers to meet a variety of instructional goals will need to become a carefully integrated part of teacher training and professional development efforts designed to change teachers' perspectives about teaching and learning.

Policy makers, administrators and teachers should consider how different types of software can help meet educational goals. Installing computers in schools is an important first step in making computers an integral part of the educational experience of US schoolchildren. More important, however, is helping teachers learn to match computer use with their instructional goals, providing different types of software consistent with these goals, ensuring teachers have access to computers in flexible workspaces, and embedding technology training in a reform-oriented professional development program (David, 1991, 1994; Sandholtz, et al., 1997; Sheingold, 1991). While computers may show great promise for improving instruction, it is ultimately teachers who will determine whether that potential is realized.

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