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# Roles for software technologies in advancing research and theory in educational psychology

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While reviews abound on theoretical topics in educational psychology, it is rare that we examine our field's instrumentation development, and what effects this has on educational psychology's evolution. To repair this gap, this paper investigates and reveals the implications of software technologies for researching and theorizing about core issues in educational psychology. From a set of approximately 1,500 articles published between 1999 and 2004, we sampled illustrative studies and organized them into four broad themes: (a) innovative ways to operationalize variables, (b) the changing nature of instructional interventions, (c) new fields of research in educational psychology, and (d) new constructs to be examined. In each area, we identify novel uses of these technologies and suggest how they may advance, and, in some instances, reshape theory and methodology. Overall, we demonstrate that software technologies hold significant potential to elaborate research in the field.

As Kuhn (1970) argued, scientific paradigms are shaped by the substance of theories, and the properties of the instruments and methodologies scientists use to investigate these theories. As computer technologies matured in sophistication and reduced in cost, educational psychologists and other researchers interested in our field's topics began to explore applications of software technologies in their research. While reviews abound on theoretical topics in educational psychology, it is rare that we examine how our field's instrumentation has developed, and what effects this has on educational psychology's evolution. To repair this gap, we reviewed applications of software technologies in educational psychology research. Our goal was to investigate and reveal what implications these technologies have for theorizing about core issues in our field. Because there are numerous and diverse studies in which software technologies have been key features, we report on what we believe is a representative sample from this population. Based on these instances, we examine how the use of software technologies can replicate and extend mainstream notions of tasks, instrumentation, scoring, and

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analyses of data. In parallel, we investigate several key theoretical issues raised by the use of software technologies in educational psychological research.

## Search procedures

Educational psychology research is indexed primarily by constructs, for example, problem solving, vocabulary knowledge, and goal orientation. We expected that identifying published research in which software technologies provided tools for research would be a challenge. We were partly right and partly wrong.

First, we surveyed a convenience sample of introductory textbooks in educational psychology with the goal of identifying key search terms in the field. We selected 15 concepts common to most textbooks including: educational psychology, perception/attention, memory/encoding/retrieval, motivation/efficacy, development (cognitive, moral, psychological), learning strategies, cognitive style/learning style, special needs, self-regulation, metacognition, intelligence, cooperat*/group processess, problem solving, reading and writing.[1] Second, we searched in PsycARTICLES and PsycINFO databases for items published between 1999 and 2004. Each search intersected computer* and one of the educational psychology concepts listed above. Articles were limited to empirical studies reported in English. Dissertations and review articles were excluded from the search.

Approximately 1,500 articles addressed theoretical and categorical constructs, well beyond our initial list. Articles were published in a very wide range of journals, many uncommon to educational psychology. Table 1 lists the top 10 educational psychology journals as well as other journals with seven or more hits publishing empirical studies using computer software technologies as research tools. Our search yielded a very broad and cross-disciplinary sample of research.

Because our allotted pages preclude presenting and critiquing the full potential of software technologies as tools for research in educational psychology, we explore four broad themes: (a) utilizing new and innovative ways to operationalize variables, collecting data and presentation instrumentation, (b) the changing nature of instructional interventions, (c) emerging areas of research in educational psychology, and (d) new constructs and re-characterizations of conventional constructs afforded by software technologies.

## Innovative ways to operationalize variables

Contemporary computer technologies provide tools for innovative operational definitions of variables. Some researchers advocate that these technologies afford opportunities to collect data that more validly represent constructs. However, research about computer-based, and adaptive computer-based tests, suggests that the psychometric properties of conventional and software-based instruments need to be re-examined.

### Researching working memory using response time and eye fixations

Working memory, a processing resource of limited capacity that holds information and simultaneously processes it (Swanson & Beebe-Frankenberger, 2004), has received

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[1] *We use the symbol / to represent 'or' and * to represent a wildcard search that looks for all terms that begin with that letter (e.g. cooperat\* = cooperative learning, cooperative processes, cooperative groups, etc.).*

**Table 1.** Journals publishing at least seven reports of empirical research or ranked among the top 10 educational psychology journals publishing reports of empirical research involving computers and educational psychology constructs in the period 1999–2004

| Journal | Hits |
| --- | --- |
| Computers in Human Behavior | 84 |
| Journal of Educational Computing Research | 61 |
| International Journal of Human-Computer Studies | 60 |
| Journal of Computer-assisted Learning | 54 |
| Behavior Research Methods, Instruments and Computers | 37 |
| Behaviour and Information Technology | 27 |
| International Journal of Human-Computer Interaction | 25 |
| British Journal of Educational Technology | 21 |
| CyberPsychology and Behavior | 21 |
| Journal of Educational Psychology | 19 |
| Instructional Science | 19 |
| Journal of Educational Multimedia and Hypermedia | 19 |
| Interacting with Computers | 18 |
| Journal of Interactive Learning Research | 18 |
| Information Technology in Childhood Education Annual | 17 |
| Neurocomputing: An International Journal | 17 |
| Social Science Computer Review | 17 |
| Decision Support Systems | 16 |
| Group Decision and Negotiation | 13 |
| Educational Technology Research and Development | 12 |
| User Modeling and User-Adapted Interaction | 12 |
| Journal of Computers in Mathematics and Science Teaching | 11 |
| Learning and Instruction | 11 |
| Psychological Reports | 11 |
| ReCALL: Journal of Eurocall | 11 |
| Ergonomics | 10 |
| Human-Computer Interaction | 10 |
| Information Systems Research | 10 |
| Medical Education | 10 |
| Reading and Writing Quarterly: Overcoming Learning Difficulties | 10 |
| Learning Environments Research | 9 |
| Communication Research | 8 |
| International Journal of Computers for Mathematical Learning | 8 |
| Journal of Computer-Mediated Communication | 8 |
| Journal of Intelligent and Robotic Systems | 8 |
| Journal of the Learning Sciences | 8 |
| Small Group Research | 8 |
| Vision Research | 8 |
| Cognitive Science | 7 |
| Educational Psychology | 7 |
| Human Factors | 7 |
| Journal of Educational Measurement | 7 |
| Neural Networks | 7 |
| Neuropsychological Rehabilitation | 7 |
| Patient Education and Counseling | 7 |
| Educational and Psychological Measurement | 6 |
| Journal of Instructional Psychology | 6 |

**Table 1.** *(Continued)*

| Journal | Hits |
|---|---|
| Journal of Experimental Psychology: Learning, Memory and Cognition | 6 |
| Applied Measurement in Education | 4 |
| Applied Psychological Measurement | 4 |
| British Journal of Educational Psychology | 3 |
| Cognition and Instruction | 3 |
| Contemporary Educational Psychology | 3 |

much attention in studies of human learning, memory, and instruction. A frequent measure of working memory administered using a computer, is a variation of Daneman and Carpenter's (1980) Working Memory Span Test. Participants silently read an interrogative sentence displayed on a monitor, and press a response key to indicate whether a provided answer is plausible. As soon as the decision is made, the software displays a new question. After a set of questions, participants are cued to recall the last word of each interrogative sentence in serial order. de Neys, D'Ydewalle, Schaeken, and Vos (2002) illustrate a group-administrable version of this procedure, called the Operation Span Test, which does not require overseeing by an experimenter. Software technologies for administering working memory span measures may be more efficient, and have the added benefits of recording data latency and response accuracy automatically, and the researcher does not have to administer the test one-to-one.

Waters and Caplan (2004) innovated a computer-enhanced measure of working memory span as an auditory 'moving windows' task. Participants' press a key to self-pace listening to segments (windows) of digitized interrogative sentences that differ in complexity and sentence type, and then press a key to register their judgment about the plausibility of a provided answer. A software program called PsyScope (Cohen, MacWhinney, Flatt, & Provost 1993) records reaction time for each button press, and response time and accuracy on each plausibility judgment. Computer recorded temporal and accuracy data allowed detailed analyses and extension of theory about the relationship between working memory and syntactic processing. Specifically, participants with low working memory scores did not show disproportionately longer listening times during the most demanding segments of complex sentences. Data collected by the software provided researchers with support for a new multi-resource model of working memory, in which syntactic processing draws on resources separate from those measured by conventional working memory tests.

Software that records eye fixations in space over time has been used to study how working memory influences reading. This technology does not interfere with normal reading by requiring the reader to press keys, or divert processing to answer interrupting prompts, as in think-aloud protocols. Also, as a person reads, reading and re-reading events can be recorded to map the reader's 'path' through material. For instance, Kaakinen, Hyoenae, and Keenan (2003) studied the effects on recall and duration of eye fixations, while encoding text as a function of readers' goals (measured by paper-and-pencil tests) and familiarity with the text concepts. Consistent with prior studies, more goal-relevant than goal-irrelevant information was recalled, regardless of a reader's prior knowledge or working memory span. Using the duration of eye fixations to gauge encoding effort, they showed that readers with high working memory scores did not need more time to process goal-relevant information when reading a familiar

text, but low memory-span readers did. Eye-tracking data led these researchers to interpret that readers with greater working memory capacity used prior knowledge to control attention resources, and thereby read more efficiently.

### Researching attention and perception using touch screen technologies and digitized pens

Attention and focus have been examined creatively using touch screen technologies. For example, Huguenin (2004) studied children's and adolescents' concentration in tasks requiring simultaneous attention to multiple cues (letters and symbols), in order to maintain continuous reinforcement. Students were provided with stimulus compounds and asked to select a specific letter – symbol combination. The software recorded the accuracy of selection, precise screen position of varying visual stimuli relative to where the participant touched, and response latency. These data revealed that individuals with severe developmental disabilities can learn to direct attention to specific stimulus features. Touch screen technologies proved to be a sensitive measure of stimulus preferences, and critical for researching the treatment of over-selective attention.

Software can be deftly applied to meet challenges in studying fine motor skill and visual discrimination. For example, Rosenblum, Parush, and Weiss (2003a, 2003b) digitally recorded the timing and nature of handwriting pauses. Heavy dark lines indicated that the writer's pen was in full contact with the screen, and fine lines indicated the pen was 'in the air'. Unlike traditional pen-and-paper-based writing assessments that focus solely on handwriting products, these data helped the researchers understand how writing difficulties are revealed in perceptual motor-control. Proficient hand writers paused (lifted the pen) at strategic points or transitions in letters or words, whereas poor hand writers lifted the pen more frequently and erratically.

### Researching studying and writing using log file traces

Logging, or event tracing, is when software collects precise data about the nature and timing of a learner's interactions with information, while not interfering with targets of research, namely, forms of cognitive processing (Hadwin & Winne, 2001). Hadwin and Leard (2001) showed how log data can be used to construct profiles of students' self-regulated learning (SRL). By combining traces of studying events, for example, highlighting and consulting objectives, with achievement test scores and students' reflections on learning, Hadwin, Boutara, Knoetze, and Thompson (in press) constructed profiles of individuals' studying strengths and weaknesses relative to a model of SRL proficiency. Patterns of skill, will, and adaptation that reflect proficiency of SRL did not correlate with performance; students who demonstrated high or emerging SRL proficiency were not always the highest performers.

Perrin (2003), and Eklundh and Kollberg (2003), used software to record data reflecting macro-, meso-, and micro-level information about how writers revise text. Their studies used S-notation, software that tracks keystrokes and then generates a detailed symbolic description. These representations of data allow inferences about writing styles and revision actions. While these particular studies originated in the field of language pragmatics, the findings, and this software tool for logging data, have much to offer educational psychologists studying processes of composition.

Log file traces may provide more accurate data about study tactics than self-report data (Winne, Jamieson-Noel, & Muis, 2002). Jamieson-Noel and Winne (2003), and

Winne and Jamieson-Noel (2002), examined relationships among self-reports about study tactics, students' judgments of learning, and software-logged data about actual use of studying tactics. They found that students were slightly positively biased (overconfident) about their achievement, and moderately positively biased (over-estimated) about their actual use of study tactics. In separate regression models, self-reports of study tactics, and traces of those same tactics each predicted achievement, however, different tactics were predictors in each regression model (self-report versus trace data). In separate principal components analyses, factors constructed from trace data described different forms of SRL than factors constructed from self-reports. Winne and Jamieson-Noel concluded that students use different criteria to self-report tactics than they do when meta-cognitively monitoring which tactics they use while studying 'on-the-fly'.

The advantage granted by observing which tactics learners actually apply versus which they report, opens new avenues to researching the standards learners use in meta-cognitive monitoring. These techniques will also aid in exploring how learners' biased perceptions about achievement shape meta-cognitive engagement. Using traces to map the short-term evolution of learning 'on-the-fly' in computer-supported instruction may also show students' self-reports, interviews, and think-aloud data in new light (Barab, Bowdish, & Lawless, 1997; Rouet & Passerault, 1999; Winne, Gupta, & Nesbit, 1994).

### Researching behaviours and attitudes using computer-based interviewing

Computers offer means for interviewing participants at a distance in surroundings that may be less intimidating than a laboratory. Newman *et al.* (2002) found the efficacy of computer-based interviewing depends upon respondents' motivations. They compared face-to-face interviewing and audio computer-assisted self-interviewing (Audio-CASI), when interviewing participants in a syringe-exchange programme. Audio-CASI was judged to elicit more frequent reporting of stigmatized behaviours, whereas face-to-face interviewing elicited frequent reporting of psychological distress. Participants selectively disclosed information to the computer that they were unwilling to disclose to a human, and disclosed information to a human interviewer that might lead to desirable outcomes such as help. These findings suggest that computerized interviewing elicits more valid responses only to certain kinds of questions.

Powell, Wilson, and Thomson (2002) compared a computerized interviewer to a live interviewer when 4- and 5-year-olds were asked to keep a secret. Children's responses to interview questions were similar in content and accuracy whether interviewed by computer or the live interviewer. However, in a follow-up interview, children were less willing to disclose the secret to the computer, than to a live interviewer. Powell, Wilson, and Hasty (2002) studied children's recall of an event, and enjoyment of the exercise, in a computerized assessment situation (Marvin), and a verbal assessment context. They found no differences in accuracy or details recalled, but the verbal interview elicited responses more consistent with free recall of the event than the computerized assessment. Together, these studies indicate that the medium for gathering data can affect the data gathered. Future research should examine contexts in which computerized interviewing affects accurate reporting, and reasons why respondents are more or less open or honest with a computerized interviewer.

### Computer-based testing

Many types of psychological assessments have been converted from paper-and-pencil format to software formats, including: clinical instruments, personality scales, job attitude surveys, and cognitive tests (Mead & Drasgow, 1993). Translating to software formats is seemingly trivial, but there is considerable practical advantage. Collecting data in typical and specialized populations becomes more affordable and feasible, even after paying for computer hardware and software. Administering instruments via software, particularly using the Internet, can significantly increase sample size by removing limits on location of respondents, and time of day for administering the survey. As an example, Groot, de Sonneville, and Stins (2004) used a software-administered battery of tests in their study of twin preschoolers' family variables, attention, and inhibition. They were able to achieve a sample of 267 twins when freed from limits of location and time of day. Administrative convenience is augmented by a substantial gain in statistical power, accompanied by significantly reduced costs and errors in entering data (Gosling, Vazire, Srivastava, & John, 2004).

### Methodological and procedural considerations in computer testing

Computers have become almost ubiquitous in education. One of the most widespread uses of computers is to construct, administer, and score tests. This has initiated new areas of research in educational measurement. In this report, we highlight key areas of discussion and research about this range of measurement issues.

#### Should participants be allowed to review and change responses?

Vispoel (2000) examined fixed-item vocabulary test performance. He found that students who were permitted to review and change answers were: (a) selective, changing answers only 3.63% of the time; (b) strategic, changing answers from wrong to right more frequently than changing them from right to wrong; and (c) successful in improving performance by changing answers by a ratio of 2.44 to 1. However, allowing students to review and change answers has implications for the time taken to complete tests. Vispoel found testing time increased by 35% when students could make these kinds of changes. For younger learners, or when many items are needed to create a representative sample of a domain, allowing test-takers to change responses may alter the concept of the reliability of test scores.

#### Are computerized tests equivalent to pen-and-paper based tests?

One challenge facing researchers in comparing computer-based tests to data collected using conventional paper-and-pencil formats, is that the nature of the tests may change. For example, item-response formats might change from Likert scale items, where responses fall into discrete nominal categories or whole number ordinal scales, to sliders – allowing a value to be selected along a continuum. Methods for making a response, and time required to respond to item formats, may differ. Progression through item order may differ if items presented via the computer are rigidly serialized and require responses, versus scanning forward or backward at any point in the paper test and omitting items.

Mead and Drasgow (1993) conducted a meta-analysis to gauge equivalence between paper-based tests of cognitive skills, and abilities relative to computerized versions.

Specifically, they examined changes in the score scale and the constructs assessed in normal populations for: (a) speeded tests, measuring processing speed through easy homogeneous items that can be answered correctly if the respondent has enough time; and (b) power tests, assessing ability on successively more difficult complex items presented under time limits. For speeded tests, they found the 'established validity of inferences made from a paper-and-pencil speeded test should not be assumed to automatically generalize to a corresponding computerized test' (p. 453). For power tests, there was little effect of test administration medium.

Recent studies show little difference between computerized and paper-and-pencil versions of tests with specialized populations, or tests that measured differences with respect to cognitive load and test-taking strategies. Preckel and Thiemann (2003) compared two versions of a test using figural matrices in the assessment of intellectual giftedness. A qualitative analysis of answers indicated that formats were comparable. Kobrin and Young (2003) examined the cognitive equivalence of software-based and paper-based tests of reading comprehension. Contrary to their hypothesis that computerized tests would place a greater load on working memory, degrade processing, and increase variation in test-taking strategies, they found no differences in search strategies or test-taking strategies. Students were asked to talk aloud during reading. Overall, the only differences were in the frequency of reading comprehension utterances on the paper-and-pencil test, and a greater frequency of re-evaluating answer choices, and reading all answer choices, before answering the question in the computerized testing environment.

## Computerized adaptive testing (CAT)

Unlike conventional tests that administer the same items to all examinees, computerized adaptive testing (CAT) dynamically selects items based on cumulative responses, and patterns of responses, to optimize estimates of trait, for example, degree of agreement. or ability level of each examinee (Wainer & Dorans, 2000). CAT provides greater efficiency and better control of measurement precision. Compared with conventional tests, adaptive tests require substantially less testing time, because they avoid administering items that are too easy or too difficult for each examinee. For example, Olsen (1990) compared a CAT version and a paper-and-pencil version of an educational achievement test. The CAT version yielded an equally precise estimate of ability, but took only 25% of the time required by the conventional test. By continuing to present items until a predetermined standard error of the trait level is achieved, CAT provides a level of precision that is more consistent across individuals and trait levels. Applications of CAT have expanded over the last decade to include credentialling examinations, admissions testing, as well as assessments of personality (Handel, Ben-Porath, & Watt, 1999), reading preparedness (Singleton, Horne, & Thomas, 1999), health status (Revicki & Cella, 1997), and a variety of other abilities and traits.

Two factors limit the widespread use of CAT in educational psychology measurement and testing. First, item response theory (IRT), the statistical model used for most CAT applications, requires items used to measure the trait to be unidimensional, because IRT models each item with a 'difficulty' parameter that pins the item to a point on the trait or proficiency dimension (Meijer & Nering, 1999). Thus, adaptive versions of an instrument cannot be developed until the latent structure for the target population has been well researched, and robust estimates of item-difficulty

parameters are in hand. Second, large banks of highly discriminating items are likely to be required to realize the benefits of adaptive tests (Xing & Hambleton, 2004). Costs to develop adaptive tests appear warranted only when there is a clear need for decreased test time, or when precise measurement is necessary at quite low or high levels of the trait (Butcher, Perry, & Hahn, 2004). For example, Archer, Tirrell, and Elkins (2001) investigated adaptive versions of the Minnesota Multiple Personality Inventory (MMPI), a 567-item personality test known to provoke unreceptivity in some examinees due to its length. However, for most of the instruments used by educational psychology researchers, the cost–benefit calculation is much less favourable for CAT.

IRT models present, at each point in the testing process, the item estimated to yield the greatest amount of information about the learner on the dimension being assessed. Although the experience of an extended series of maximally self-informing activities seems to have significant implications for motivation, self-regulation, teaching, and learning, we could find no work applying IRT principles beyond standardized testing to self-assessment, adaptive tutoring systems, or educational gaming. From the perspective of achievement goal theory (e.g. Elliot & McGregor, 2001), individuals seeking to know or demonstrate their competence should be strongly attracted to tasks and games grounded in an IRT model. Further, the performance feedback offered by adaptively selected tasks might be especially effective in helping learners to calibrate judgments of their learning. We predict that CAT is an area ripe for quite a variety of future research.

## Changing nature of instructional interventions

Computer technologies offer opportunities to change the nature of instructional interventions researched in educational psychology. We identified two broad categories of interventions. The first includes tools for delivering interventions. In reading, for example, these include tools for helping consumers of empirical research to critically examine it (Varnhagen & Digdon, 2002), tools for remediating deficits in auditory temporal processing (Fast ForWord; Troia & Whitney, 2003), and multimedia talking books (Chera & Wood, 2003) to name a few. In the area of composition, researchers have studied the effects of using word processing, word prediction, and capitalization tools on production (e.g. Handley-More, Deitz, Billingsley, & Coggins, 2003; Traynor, 2003), and compared technology-enhanced writing of scripts for movies for improving expressive writing skills (Cramer & Smith, 2002). Johari (2003) studied the effects of multimedia problem-solving instruction augmented with reflective questions and graphing tools.

Using computers to deliver instruction can allow participants to work individually and in their own time. Researchers do not have to use intact classes at one point in time to study the effectiveness or effects of an intervention. There are, however, several potential limitations of these kinds of studies. In many such interventions, learners have little control over timing and the path through materials, two variables they can control in authentic contexts. Second, there is little dynamic individualized support offered to a learner in contrast to the availability of such help in real-life studying. A third limitation is that software features typically fall short of what Lajoie (1993) calls a 'cognitive tool'; that is, a software feature that supports cognitive processes by taking over some of the work for the learner, to free other resources for cognitive engagement. Finally, Lajoie (2000) suggests an area needing work is how software learning environments are

conceptualized in the role of a model. Is it the system or a human partner who models? Amongst all these issues, the important point is not so much which technologies are used, as how learning and instructional theories can be tested and advanced using contemporary technologies, and, subsequently, how these technologies may be applied in authentic settings.

The second category of intervention studies uses computers to guide and tutor learning. This represents an innovative and exciting line of investigation, which could significantly shape research that aims to study and improve instructional processes and scaffold learning. These types of technologies allow us to study the process of instruction, and experiment with changes in how and when students are supported.

### Software to tutor or provide individualized computer assisted instruction (CAI)

A defining attribute of tutoring technologies is that the software tailors its support based on how a student engages with information and how they use the software tools for learning. In general, research aims to emulate human tutors to investigate effects of tutoring on constructs such as learning, memory, and motivation.

### Reading

In a small pilot study, vanDaal and Reitsma (2000) used software called Leescircus as part of kindergarten children's formal reading and spelling instruction. With Leescircus, students engage with interactive multimedia drill-and-practice reading and spelling exercises that are targeted to specific emergent reading skills, for example, indicating the position of a sound in a word. This is accompanied by immediate, corrective, individualized feedback. Children using Leescircus learned early reading skills much faster than peers in a regular reading programme. They also learned to read more words and non-words, and to name more letters than peers participating in regular instruction. In a second study involving children with low motivation and beliefs that they were incompetent readers, students using Leescircus showed more positive behaviour during computer-based reading activities, and learned more words correctly than students in regular instruction.

Computer tutors providing Vygotskian-like scaffolding have been used to help children with writing tasks (Holdich & Chung, 2003). HARRY is a cognitive tool designed to promote higher-order thinking about writing. Holdich and Chung used a model of expert writing to design conversational prompts that impart knowledge about narrative writing processes like brainstorming, planning, composing, and revising (editing). HARRY presents these prompts asking the student to tell him more, much like a writing version of the somewhat tongue-in-cheek Rogerian counsellor, ELIZA (Weizenbaum, 1976). The student responds in a separate field and successively constructs the narrative piece by piece. HARRY also provides more traditional writing suggestions in a separate information box. Holdich and Chung reported only a preliminary evaluation of HARRY. Notwithstanding, we believe this type of system offers much potential to guide writing and other processes, as it collects data about the development of products and processes. In moving toward more ecologically valid studies of learning, motivation, memory, and other constructs, these systems are relatively easy to implement in schools.

### Problem solving and inquiry learning

Shimoda, White, and Frederiksen (2002) experimented with modifiable software advisors in an open ended science inquiry project (cf. White, Shimoda, & Frederiksen, 1999). Software advisors in the SCI-WISE environment provide advice, prompts, and content information as text. In the 2002 study, task advisors provided guidance for task completion and performance (performance orientation), general purpose advisors gave guidance for understanding and using inquiry skills and strategies (learning and mastery orientations), and system development advisors offered guidance for modifying the system to better meet personal learning goals (personal knowledge building). A key component of the SCI-WISE system is that it is interactive and modifiable. Students can alter settings for the advisors to change the kind and amount of support they receive. Shimoda *et al.* (2002) studied how these software advisors were used by students with differing goal orientations to develop inquiry skills and concepts. One group experienced the modifiable version of the software just described, while a second group was provided with advice, but could not select the type of advice they preferred. Shimoda *et al.* reported two important findings. First, knowledge-oriented students who used the modifiable advisors rated SCI-WISE as more helpful than task-oriented students did. Second, knowledge-oriented students who used the non-modifiable version had higher post-test scores than students using the modifiable version. This finding may have been because students experiencing the non-modifiable version received more advice overall, whereas the modifiable version provided advice only when requested. In other words, students may not have optimally self-regulated to take advantage of the modifiable version.

Research in this area makes good use of the power of software technologies to study and experiment with models of support, guidance, and scaffolding, in ways that are impractical and sometimes impossible in classrooms. Subtle features of support can be adapted and tested without retraining live tutors or having to collect and analyse treatment-fidelity data.

### Computer supported collaborative work (CSCW)

Advanced computer technologies afford researchers opportunities to study detailed aspects of group processes and products, including discourse patterns that facilitate and derail progress, how groups identify and adjust goals, interim products, and many other variables that have previously been difficult to capture and correlate across the timeline of group work. For example, Hmelo-Silver (2003), and Hmelo, Nagarajan, and Day (2000) investigated how collaborative strategies advance as students use technologies to develop interim products. Medical students were assigned the task of designing a Phase 2 clinical trial. The task was collaboratively completed on the computer using software tools. As students exchanged ideas and discussed the task in face-to-face exchanges, the software created a record detailing the developmental trajectory of the group's solution to the design project. Examining traces of collaborative dialogue, as well as changes in collaborative processes, allows researchers to pinpoint how the product matures through group interaction.

Similarly, Fischer, Bruhn, Grasel, and Mandl (2002) explored the hypothesis that when a software concept mapping tool required collaborators to explicitly identify types of information and types of links, students would externalize information that, in turn, would enhance the development of co-constructed meaning. Correlating features of evolving products with features of students' collaborative dialogue, Fischer and

colleagues observed that students who used mapping tools that highlighted types of information and types of links, referred to more relevant concepts, risked more conflicts, and were more successful in integrating prior knowledge into their co-constructed solution.

Beyond using software technologies to track how products develop in collaborative groups, research on computer-mediated communication (CMC) focuses on discourse processes supported by software. For example, Newlands, Anderson, and Mullin (2003) compared the structure and length of dialogues and collaborators' conversational moves and games, when participants used a text chat tool (CMC) versus speech only. Task performance initially suffered and then improved with experience during CMC. As collaborators became moderately experienced with the CMC environment, their instructions to one another became more concise and precise. Similarly, Schellens and Valcke (2004) examined the effects of dialogue generated in asynchronous versus synchronous study groups on the quality of academic discourse and construction of knowledge. Synchronous discussions in this study tended to be task focused, to stay task focused, and contain high knowledge construction.

Other variables examined in studies using CMC include impressions participants form of others' personality (Hancock & Dunham, 2001a), motivation (Guzley, Avanzino, & Bor, 2001), cross-cultural differences in online communications (Kim & Bonk, 2002), the effects of augmenting CMC environments with turn-taking tools to guide conversation (Hancock & Dunham, 2001b), and job satisfaction when employees use CMCs (Amaeshi, 2002). CMC spawns differences in the ways people interact versus face-to-face environments as a function of temporality (synchronous vs. asynchronous), anonymity (knowing who you are speaking with), and spatiality (arrangement and proximity of participants; Smith, Alvarez-Torres, & Zhao, 2003). Although new multimedia programs such as Palace and Microsoft Chat afford opportunities to control special arrangements of settings, avatars (speaker images), and objects, these dimensions have not been adequately researched in the literature in terms of psychological constructs such as learning, problem-solving, and motivation.

### Supporting CSCW

Little research has investigated how to guide and sustain productive teamwork in software collaboration environments. But research about breakdowns in CSCW may provide some directions for researching these environments. Carroll, Neale, Isenhour, Rosson, and McCrickard (2003) identified four factors at the root of collaboration breakdowns, and recommended designs for notification systems to remedy such breakdowns. First, students identified situation factors that interfered with productivity. For example, as deadlines or completion dates change for one member of a group, the rest of the group wanted to know about those changes so they could adjust related goals and plans. Providing means for tracking changes in task situation, and reasons for those changes, may enhance collaborative productivity. Second, students described breakdowns in group factors often caused by misperceptions about collaborators' abilities, lack of trust, and lack of cohesiveness about paths toward goals. This suggests that peers in CSCW environments might profit from access to tools for chatting and developing rapport, and features (such as avatars) that allow them to represent aspects of their personalities to the group. Third, task factors challenged groups. Initially-shared goals for task completion tended to fall apart over time and iterations, because it was

cumbersome to oscillate between planning, dialogue, and other tools for coordinating goals and subtasks. Timeline tools that allow students to categorize documents, notes, and chats organized according to time on one dimension, and category or subgoal on another dimension, may enhance task coordination. Fourth, tool complexity posed challenges because, as support and planning tools become more complex, they become less useful. When different displays notified students of different updates, students just tended to ignore entire notification windows. This begs for research that explores how to integrate notification tools with displays of updated information about who has changed what, about tasks, events, and products.

Guzdial and Turns (2000) experimented with several classes of tools designed to promote and guide CSCW in their CaMILE system. Discussion management features were intended to help students understand the flow of discussion, and follow historical threads in it, by tagging notes as the original, replies, and add-ons. Facilitation features were designed to provide scaffolding for presenting ideas by classifying notes and contributions into useful categories such as new theory, evidence, and so forth. For example, a theory note might provide fields for entering the theory name, author, summary, evidence, and example. Finally, anchoring features allowed learners to tag information to make it easier for collaborators to find and organize, effectively defining pivots for entering and following threads of discussion. Guzdial and Turns observed that CaMILE did not affect levels of collaborators' participation, but did lengthen discussion threads.

Kreijns, Kirschner, and Jochems' (2003) review identified two major pitfalls in designs for CSCW environments. First, social interaction is often taken for granted simply because the tools are made available. Beyond tools for collaboration, learners need structured and scaffolded support for enacting the collaboration process, but little research exists to inform the design of coaching tools. Second, CSCW environments orchestrate and emphasize collaborative interactions focused on the task, but do not correspondingly support the development of a collaborative community with norms that allow members to feel safe, take risks, and share ideas. Kreijns *et al.* offered six researched-based recommendations for designing CSCW environments: (a) design peer interaction into the instruction, (b) facilitate the creation of relationships of trust and a sense of community, (c) make use of non-task and task contexts that afford opportunities for informal discussion, (d) apply multiple instructional approaches to enhance collaborative learning (e.g. cognitive-specific, collaborative, positive inter-dependence activities), (e) move toward student-centred approaches to instruction, and (f) design sociable environments.

Future research needs to examine the effectiveness of tools and interventions that address these six recommendations. We found few studies that employed or studied collaborative support tools. For the most part, there was little support provided for the task, where there was support, it was given with little or no guidance about how to collaborate. A programme of research by Carroll *et al.* (2003) was an exception. They have begun experimenting with notification systems to support collaborative awareness, by providing event-triggered notices related to peripheral aspects of the task on which members' collaborate. An example is notice of an incoming e-mail from a collaborator or phases of task completion. Notifications, according to Carroll *et al.*, should support social awareness including 'who is here and who can I work with?', action awareness that involves keeping track of the state of task and relevant objects such as shared documents and resources, and activity awareness of situational constraints, social expectations within the group, shared goals and the status of those

goals. Research that examines the effectiveness of these types of collaborative tools in terms of declarative, procedural, and conditional knowledge about collaboration is sorely needed.

## New fields of research for educational psychology

As well as contributing to research on constructs in educational psychology, software technologies have opened avenues for a new discipline of research, human computer interaction (HCI). HCI is '. . . concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them' (Hewett *et al.*, 1992). When HCI investigates psychological factors that bear on designing instructional software environments, it has an important place in the study of educational psychology.

However, current HCI research is often not linked to educational psychology. Zhang and Li's (2004) review of empirical articles in two prominent HCI journals indicated that work on issues relevant to educational psychology such as learning, motivation, emotion, and individual differences was low, varying from 3.3% to 6.5% of the 307 articles reviewed. No studies directly addressed educational issues.

### *HCI as a context for educational psychology research*

Studies of how learners respond to, and recall, information as a function of variations in text layout are common to educational psychology. A parallel to these variables that is beginning to be studied in software environments is hypertext, 'computer mediated text in which highlighted words or text enable readers to interactively determine the order and level of detail by serving as links to other excerpts or documents of supporting information' (Lee & Tedder, 2003, pp. 767–768). Lee and Tedder compared the effects of traditional text, structured hypertext, and networked hypertext on readers' recall. Traditional text is linear text read from top to bottom. Structured hypertext consists of each subtopic being presented through hyperlinks to different screens. Readers can read topic to topic, and progress to different depths for each topic. Networked hypertext is a web of interconnected excerpts linked by highlighted text and terms in which readers can move freely. Lee and Tedder observed that recall was highest in the structured hypertext condition, even after total reading time was accounted for as a covariate in their analysis. This effect was strongest for students with low working memory.

Given the attraction to, and widespread use of, the World Wide Web in modern education, more research like that of Lee and Tedder (2003) should be done. We propose that, rather than just replicating traditional research about text processing in new media environments, theory might benefit most by merging work on software design and individual differences in learning. Such work might test adaptive systems, in which text presentation moves toward more complex structures, such as networked hypertext, as the reader develops expertise. Helping learners do this on their own, as self-regulated learning, would be a major accomplishment (see Nesbit & Winne, 2003).

### *Pedagogical agents*

Interface agents are computer programs usually consisting of an animated human-like personae with audible speech, for example, an animated paper clip, or a speaking

wizard. They are designed to help users accomplish tasks (Dehn & van Mulken, 2000). Pedagogical agents are a subcategory of these programs that may provide task instructions, background information, hints and just-time information, or feedback. Pedagogical agents may also deploy specific tutoring strategies, such as allowing the learner to find solutions to a problem before giving explanations relevant to the learner's choices (Moreno, Mayer, Spires, & Lester, 2001). This 'hot' area at the juncture of HCI and educational psychology, comprised the majority of citations we observed in the *Journal of Educational Psychology*.

Research demonstrates that pedagogical agents can produce higher levels of learner interest, retention, and knowledge transfer than narrative text that provides equivalent information content (Moreno & Mayer, 2004; Moreno *et al.*, 2001). The positive effects of pedagogical agents appear to be due to using audible speech rather than text, personalized messages (e.g. use of 'I', and 'you') rather than third-person pronouns, and coaching strategies that invite a learner to try constructing solutions to problems before receiving explanatory feedback (Atkinson, 2002; Craig, Gholson, & Driscoll, 2002; Mayer, Dow, & Mayer, 2003; Moreno & Mayer, 2000, 2004; Moreno *et al.*, 2001). Several of these studies report that discarding the visual form of agents, while retaining auditory features, made little or no difference to measured outcomes.

## New constructs or conventional constructs with a new spin

The introduction of computer technologies to educational research and instructional design has also resulted in the emergence of new or evolving constructs for research. Due to space limitations we elaborate on three new constructs; that is, cognitive load, computer efficacy, and computer anxiety, and acknowledge others such as: (a) gender differences in computer use (e.g. Blumberg & Sokol, 2004; Durndell & Haag, 2002; Miller, Schweingruber, & Brandenburg, 2001; Shapka & Ferrari, 2003; Venkatesh, Morris, & Ackerman, 2000), and (b) computer learning styles (Ames & Ames, 2003).

### Cognitive load

Recent work on cognitive load in educational psychology has become a predominant theory for explaining cognitive processes in multimedia learning environments (Brunken, Plass, & Leutner, 2003). Cognitive load refers to the memory processing load associated with various learning environments. Cognitive load can be attributed to the structure and complexity of the content studied, intrinsic cognitive load refers to the way content is organized and presented, extraneous cognitive load is the effort applied by learners to comprehend and process information, and germaine cognitive load refers to load produced when trying to understand and learn content (Brunken *et al.*, 2003; Pollock, Chandler, & Sweller, 2002; Sweller, 1999). 'The foundation and implications of [cognitive load theory] can be especially well investigated in the context of multimedia learning, because the use of this technology as instructional medium involves perceiving and processing information in different presentation modes and sensory modalities' (Brunken *et al.*, 2003, p. 54).

### Computer efficacy

Much like self-efficacy in learning, computer efficacy in computer-based learning has proven to influence learning engagement and outcomes. For example, Cassidy and

Eachus (2002) reported that: (a) computer efficacy is correlated with computer experience and familiarity with software packages, (b) owning a computer and having training on a computer are related to higher computer efficacy, and (c) males had significantly higher computer efficacy than females. Computer efficacy has also been correlated with the number of correct search results in a computer-based search activity (Thompson, Mariac, & Cope, 2002), types of computer programs with which users have experience (Hasan, 2003), and motivation to use the World Wide Web (Liaw, 2002). Furthermore, LaRose, Mastro, and Eastin (2001) proposed a socio-cognitive model of Internet use including self-efficacy and self-disparagement that accounted for 60% of the variance in Internet usage.

### Computer anxiety

Computer anxiety is another relatively new construct. In addition to testing the psychometric properties and factor structure of computer anxiety scales (e.g. Barbeite & Weiss, 2004; Marcoulides, Stocker, & Marcoulides, 2004), studies have begun to examine anxiety characteristics of various populations of computer users, and the relationship between anxiety and other constructs. For example, Namlu (2003) reported that computer anxiety has been related to several personality and demographic variables (e.g. Goldstein, Dudley, Erickson, & Richer, 2002). Researchers have examined the relationship between computer anxiety and other factors such as test anxiety, reporting that computer anxiety is negatively correlated with computer self-efficacy, attitudes to the Internet, and duration of Internet use (Durndell & Haag, 2002). More recently, research has begun to investigate changes in computer anxiety due to various instructional interventions. For example, Namlu found that computer anxiety decreased from pre- to post-test when students were taught learning strategies.

As computers have become more prominent tools for learning and research, new educational psychology constructs have arisen, and others have been customized for a new research context. As a discipline concerned with teaching and learning processes, the methods, theories and constructs central to educational psychology should play a more central role in the development and study of instructional technologies.

## Conclusions

The scope of educational psychological research using software technologies is not as broad as the field itself, but it is still considerable. What are the advantages and disadvantages of using software technologies in educational psychology research? Is this new medium changing the nature of research? Does the use of computer technologies in educational psychology research begin to blur the boundaries of our discipline?

### Advantages of using software in educational psychological research

First, software can record data that are impractical to gather otherwise. For instance, coupling trace-gathering technologies and eye-tracking technologies generates data about how learners distribute attention and operate on information, with a degree of detail unavailable to researchers using conventional materials and methodologies. Because these data can be time-stamped to the millisecond (approximately), and already exist in electronic form, portraits of microgenetic development can be painted by other software nearly instantaneously. How these qualities can advance the field remains to be

developed, but, as in other sciences, we forecast that new instrumentation has strong potential to spur original kinds of theorizing.

Second, software can be programmed to interact conditionally on learners' behaviour, and will do so with perfect reliability. This stands in contrast to what are, in our experience, inevitable perturbations to the operational definition of treatment and control variables as these are put into practice by human researchers. Moreover, software can be programmed to adapt these rules of interaction. Together, these features hold promise for improving experimental control. Most challenging, and, we suggest, most likely to advance theory, is the requirement that researchers who design such software systems make explicit the triggers for interactions (the conditions in condition–action production systems), and the functions that map specific conditions to particular actions. Externalizing the common sense that we expected research assistants or confederates to use affords unpacking, thoroughly specifying, and modelling the forms of interaction in exacting detail. Such precision has been a hallmark of progressive science.

Third, software offers thoroughness in gathering data that is almost impossible to match when human researchers collect data. Not only does software not miss observations, it observes without bias, at least, without bias that is not intended by the programmer. Where it would be impractical to have an observer present to gather data on every occasion, for example, the computational steps a student performs, software systems can do this when students use them to study and learn. This extends not only the volume of data, but also the boundaries of data reliability and generalizability.

### Effects of software technologies on research in educational psychology

First, new issues arise with respect to measuring constructs. For example, in a paper-and-pencil medium, the question of whether respondents should be allowed to review items and change responses has almost never been raised. In software media, this issue is highlighted.

Second, software creates new conditions under which learners learn, and collaborators collaborate. Participants' perceptions of these conditions may affect how they engage in the tasks investigated in research, and may differ from perceptions about parallel circumstances in other media. Also, constructs such as computer anxiety and computer self-efficacy have been postulated and warrant research to map their place, if any, in the nomological network of individual differences.

Third, software environments afford new ways to operationalize variables in educational psychology. Capabilities to control and observe timing, to measure visual attention to specific information, and to track in very fine detail how participants sample and operate on information over time, invite conceptual reanalysis of the pivot points in theories. For instance, because it is now possible to record literally every overt operation a learner performs on text, diagrams, animations, and video presentations, which operations does theory justify as ignoring in modelling performance? We forecast that matters of grain size may have a significant impact on conceptualizing causal factors in accounts of learning, motivation, self-concept, and other variables throughout the field.

Fourth, software technologies now in schools are supplements (positive, we hope), in almost every subject area. Moreover, because collaboration using common software such as e-mail and chat tools is so easy, collaboration will probably become more frequent. Students who may have telephoned one another last year about homework

problems may share screen displays this year. Such changes to the school environment invite questions about communications and social interactions at multiple levels: the individual, groups, classrooms, and extended 'virtual' groups such as web logs (blogs), that connect students in one geographical location to peers and experts (not necessarily older) beyond their community, and even their country.

Fifth, because software can record data, perform computations on it, and nearly instantaneously tailor its interface and functionality based on those computed results, opportunities arise to model learning in which independent variables are dynamic, recursive functions of unfolding conditions, rather than static interventions independent of conditions. And, because students can use such software over long periods, even years of schooling, opportunities to study development are significantly extended. These two features have potential to reshape theories of learning and motivation as constructs in transition, rather than states and traits. Custom software environments such as our gStudy (Winne, Hadwin, Nesbit, Kumar, & Beaudoin, 2004) provide tools for constructing novel research environments that allow for careful and precise logging of a wide variety of traces of events.

### Closing thoughts

We conjecture that there are two main obstacles to wider and more frequent use of software technologies in research. First, there are not yet many software systems that are as easy to use and as 'handy' as conventional materials. This is changing rapidly. Second, using software technologies in experimental research requires computers to run the software. While desktop systems are now relatively inexpensive, and portable hardware is becoming ever smaller, more reliable, and wirelessly attachable to the Internet, computer hardware is nonetheless expensive equipment relative to many conventional materials. There are, as well, additional costs attending the use of software in research that come in the form of operating systems, software purchases, and maintenance. However, costs are spiralling downward, and many funding agencies seem willing to entertain that educational psychology needs equipment just as much as do researchers in engineering and medicine.

Beyond modest generalizations of prior studies' methodological formats, we urge that more researchers consider how they could use modern software technologies to investigate topics in educational psychology. In doing so, we suggest that the particular strengths of software systems be exploited. What are these strengths? Recognizing that not every question in the field of educational psychology should or could be studied using software technologies, we believe there is broad scope and much profit to be gained by applying these technologies in our research programmes. Given the rapid growth in educators' and students' uses of computers in the industrialized countries, it may be necessary to 'take the plunge' if only to parallel the circumstances of tomorrow's schooling.

Our review has only scratched the surface of how software technologies are being used in researching and theorizing about educational psychology. Because space was limited, we could not present other large areas of research, such as assistive technologies, and games and simulations, where significant uses of software technologies are evident. By sketching an array of software technologies across a limited number of educational psychology constructs, we compromised depth for breadth regarding potentials of these technologies in our field. For the most part, the

four themes introduced in this review paper represent dramatically different approaches and perspectives of technology impact.

We conclude with two important revelations about the cross-disciplinary nature of research educational psychology. First, research with strong connections to educational psychology appears in literature and journals that extend well beyond conventional educational psychology journals (see Table 1). Second, as the field of educational technology continues to explode, a challenge is to find ways of indexing a wide array of journals in educational psychology databases, so that we do not become isolated from contemporary, innovative, and relevant research that identifies itself as educational technology. We note that our searches in the PsycINFO and PsycARTICLES databases excluded journals such as *Educational Technology Research and Development*, and the *International Journal of Artificial Intelligence in Education*. Both publish research in instructional technology which harnesses cutting-edge software technologies and adaptive tutoring systems; areas that promise to stimulate our field.

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## References

Amaeshi, K. (2002). Computer–Mediated Communication Technologies (CMCTS) and user's job satisfaction. *IFE Psychologia: An International Journal*, *10*, 100–113.

Ames, P. C., & Ames, P. C. (2003). Gender and learning style interactions in students' computer attitudes. *Journal of Educational Computing Research*, *28*(3), 231–244.

Archer, R. P., Tirrell, C. A., & Elkins, D. E. (2001). Evaluation of an MMPI-A short form: Implications for adaptive testing. *Journal of Personality Assessment, 76*(1), 76–89.

Atkinson, R. K. (2002). Optimizing learning from examples using animated pedagogical agents. *Journal of Educational Psychology, 94*, 416–427.

Barab, S. A., Bowdish, B. E., & Lawless, K. A. (1997). Hypermedia navigation: Profiles of hypermedia users. *Educational Technology Research and Development*, *45*(3), 23–41.

Barbeite, F. G., & Weiss, E. M. (2004). Computer self-efficacy and anxiety scales for an internet sample: Testing measurement equivalence of existing measures and development of new scales. *Computers in Human Behavior, 20*(1), 1–15.

Blumberg, F. C., & Sokol, L. M. (2004). Boys' and girls' use of cognitive strategy when learning to play video games. *Journal of General Psychology, 131*, 151–158.

Butcher, J. N., Perry, J., & Hahn, J. (2004). Computers in clinical assessment: Historical developments, present status, and future challenges. *Journal of Clinical Psychology, 60*(3), 331–345.

Brunken, R., Plass, J. L., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 53–61.

Carroll, J. M., Neale, D. C., Isenhour, P. L., Rosson, M. B., & McCrickard, S. (2003). Notification and awareness: Synchronizing task-oriented collaborative activity. *International Journal of Human-Computer Studies, 58*, 605–632.

Cassidy, S., & Eachus, P. (2002). Developing the computer user self-efficacy (CUSE) scale: Investigating the relationship between computer self-efficacy, gender and experience with computers. *Journal of Educational Computing Research, 26*(2), 133–153.

Chera, P., & Wood, C. (2003). Animated multimedia 'talking books' can promote phonological awareness in children beginning to read. *Learning and Instruction, 13*(1), 33–52.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research: Methods, Instruments, and Computers, 25*, 257–271.

Craig, S. D., Gholson, B., & Driscoll, D. M. (2002). Animated pedagogical agents in multimedia educational environments: Effects of agent properties, picture features and redundancy. *Journal of Educational Psychology, 94*, 428–434.

Cramer, S., & Smith, A. (2002). Technology's impact on student writing at the middle school level. *Journal of Instructional Psychology, 29*(1), 3–14.

Daneman, M., & Carpenter, P. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning and Verbal Behavior, 19*, 450–466.

Dehn, D. M., & van Mulken, S. (2000). The impact of animated interface agents: A review of empirical research. *International Journal of Human-Computer Studies, 52*, 1–22.

de Neys, W., D'Ydewalle, G., Schaeken, W., & Vos, G. (2002). A Dutch, computerized, and group administrable adaptation of the operation span test. *Psychologica Belgica, 42*(3), 177–190.

Durndell, A., & Haag, Z. (2002). Computer self-efficacy, computer anxiety, attitudes towards the internet and reported experience with the internet, by gender, in an East European sample. *Computers in Human Behavior, 18*(5), 521–535.

Eklundh, K. S., & Kollberg, P. (2003). Emerging discourse structure: Computer-assisted episode analysis as a window to global revision in university students' writing. *Journal of Pragmatics, 35*(6), 869–891.

Elliot, A. J., & McGregor, H. A. (2001). A 2 * 2 achievement goal framework. *Journal of Personality and Social Psychology, 80*, 501–519.

Fischer, F., Bruhn, J., Grasel, C., & Mandl, H. (2002). Fostering collaborative knowledge construction with visualization tools. *Learning and Instruction, 12*(2), 213–232.

Goldstein, S. B., Dudley, E. A., Erickson, C. M., & Richer, N. L. (2002). Personality traits and computer anxiety as predictors of Y2K anxiety. *Computers in Human Behavior, 18*(3), 271–284.

Gosling, S. D., Vazire, S., Srivastava, S., & John, O. P. (2004). Should we trust web-based studies? A comparative analysis of six preconceptions about internet questionnaires. *American Psychologist, 59*(2), 93–104.

Groot, A. S., de Sonneville, M. J., & Stins, J. F. (2004). Familial influences on sustained attention and inhibition in preschoolers. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 45*(2), 306–314.

Guzdial, M., & Turns, J. (2000). Effective discussion through a computer-mediated anchored forum. *Journal of the Learning Sciences, 9*(4), 437–469.

Guzley, R. M., Avanzino, S., & Bor, A. (2001). Simulated computer-mediated/video-interactive distance learning: A test of motivation, interaction satisfaction, delivery, learning & perceived effectiveness. *Journal of Computer-Mediated Communication, 6*(3). Retrieved 8 June 2004, from http://www.ascusc.org/jcmc/vol6/issue3/guzley.html.

Hadwin, A. F., Boutara, L., Knoetze, T., & Thompson, S. (in press). Cross case study of self-regulation as a series of events. *Educational Research and Evaluation*.

Hadwin, A. F., Leard, T. (2001, April). Navigation profiles: Self-regulating learning examined through five analytical representations of logfile data. In A. F. Hadwin (organizer), *Logfile navigation profiles and analysis: Methods for tracking and examining hypermedia navigation*. Symposium presented the Annual Meeting of the American Educational Research Association, Seattle, WA.

Hadwin, A. F., & Winne, P. H. (2001). CoNoteS2: A software tool for promoting self-regulation and collaboration. *Special Issue in Educational Research and Evaluation*, 7(3–2), 313–334.

Hancock, J. T., & Dunham, P. J. (2001a). Impression formation in computer-mediated communication revisited: An analysis of the breadth and intensity of impressions. *Communication Research, 28*(3), 325–347.

Hancock, J. T., & Dunham, P. J. (2001b). Language use in computer-mediated communication: The role of coordination devices. *Discourse Processes, 31*(1), 91–110.

Handel, R. W., Ben-Porath, Y. S., & Watt, M. (1999). Computerized adaptive assessment with the MMPI-2 in a clinical setting. *Psychological Assessment, 11*, 369–380.

Handley-More, D., Deitz, J., Billingsley, F. F., & Coggins, T. E. (2003). Facilitating written work using computer word processing and word prediction. *American Journal of Occupational Therapy, 57*(2), 139–151.

Hasan, B. (2003). The influence of specific computer experiences on computer self-efficacy beliefs. *Computers in Human Behavior, 19*(4), 443–450.

Hewett, T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M. *et al.*, (1992). *ACM SIGCHI Curricula for Human-Computer Interaction. Association for computing machinery.* Retrieved August 19, 2004, from http://sigchi.org/cdg/index.html.

Hmelo, C. E., Nagarajan, A., & Day, R. S. (2000). Effects of high and low prior knowledge on construction of a joint problem space. *Journal of Experimental Education, 69*(1), 36–56.

Hmelo-Silver, C. E. (2003). Analyzing collaborative knowledge construction: Multiple methods for integrated understanding. *Computers and Education, 41*, 397–420.

Holdich, C. E., & Chung, P. W. H. (2003). A 'computer tutor' to assist children develop their narrative writing skills: Conferencing with HARRY. *International Journal of Human-Computer Studies, 59*, 631–669.

Huguenin, N. H. (2004). Assessing visual attention in young childern and adolescents with severe mental retardation utilizing conditional-discrimination tasks and multiple testing procedures. *Research in Developmental Disabilities, 25*, 155–181.

Jamieson-Noel, D. L., Winne, P. H. (2003). Comparing self-reports to traces of studying behavior as representations of students' studying and achievement. *German Journal of Educational Psychology, 17* (3/4), 159–171. [*Zeitschrift für Pädagogische Psychologie*].

Johari, A. (2003). Effects of inductive multimedia programs in mediating word problem translation misconceptions. *Journal of Instructional Psychology, 30*(1), 47–68.

Kaakinen, J. K., Hyoenae, J., & Keenan, J. M. (2003). How prior knowledge, WMC, and relevance of information affect eye fixations in expository text. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*(3), 447–457.

Kim, K. J., & Bonk, C. J. (2002). Cross-cultural comparisons of online collaboration. *Journal of Computer-Mediated Communication, 8*(1). Retrieved June 2004 from http://www.ascusc.org/jcmc/vol8/issue1/kimandbonk.html

Kobrin, J. L., & Young, J. W. (2003). The cognitive equivalence of reading comprehension test items via computerized and paper-and-pencil administration. *Applied Measurement in Education, 16*(2), 115–140.

Kreijns, K., Kirschner, P. A., & Jochems, W. (2003). Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: A review of the research. *Computers in Human Behavior, 19*, 335–353.

Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago, IL: University of Chicago Press.

Lajoie, S. (1993). Computer environments as cognitive tools for enhancing learning. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 261–288). Hillsdale, NJ: Lawrence Erlbaum.

Lajoie, S (2000). Introduction: Breaking camp to find new summits. In S. Lajoie (Ed.), *Computers as cognitive tools: No more walls* (pp. xv–xxxii). Mahwah, NJ: Lawrence Erlbaum.

LaRose, R., Mastro, D., & Eastin, M. S. (2001). Understanding internet usage: A social-cognitive approach to uses and gratifications. *Social Science Computer Review, 19*(4), 395–413.

Lee, M. J., & Tedder, M. C. (2003). The effects of three different computer texts on readers' recall: Based on working memory capacity. *Computers in Human Behavior, 19*(6), 767–783.

Liaw, S. S. (2002). Understanding user perceptions of World-Wide Web environments. *Journal of Computer Assisted Learning, 18*(2), 137–148.

Marcoulides, G. A., Stocker, Y. O., & Marcoulides, L. D. (2004). Examining the psychological impact of computer technology: An updated cross-cultural study. *Educational and Psychological Measurement, 64*(2), 311–318.

Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: What works in the design of agent-based microworlds? *Journal of Educational Psychology, 95*, 806–812.

Mead, A. D., & Drasgow, F. (1993). Equivalence of computerized and paper-and-pencil cognitive ability tests: A meta-analysis. *Psychological Bulletin, 114, 449–458.*

Meijer, R. R., & Nering, M. L. (1999). Computerized adaptive testing: Overview and introduction. *Applied Psychological Measurement, 23*(3), 187–194.

Miller, L. M., Schweingruber, H., & Brandenburg, C. L. (2001). Middle school students' technology practices and preferences: Re-examining gender differences. *Journal of Educational Multimedia & Hypermedia, 10,* 125–140.

Moreno, R., & Mayer, R. E. (2000). Engaging students in active learning: The case for personalized multimedia messages. *Journal of Educational Psychology, 92,* 724–733.

Moreno, R., & Mayer, R. E. (2004). Personalized messages that promote science learning in virtual environments. *Journal of Educational Psychology, 96*(1), 165–173.

Moreno, R., Mayer, R. E., Spires, H. A., & Lester, J. C. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? *Cognition and Instruction, 19,* 177–213.

Namlu, A. G. (2003). The effect of learning strategy on computer anxiety. *Computers in Human Behavior, 19*(5), 565–578.

Nesbit, J. C., & Winne, P. H. (2003). Self-regulated inquiry with networked resources. *Canadian Journal of Learning and Technology, 29,* 71–92.

Newlands, A., Anderson, A. H., & Mullin, J. (2003). Adapting communicative strategies to computer-mediated communication: An analysis of task performance and dialogue structure. *Applied Cognitive Psychology, 17*(3), 325–348.

Newman, J. C., Des Jarlais, D. C., Turner, C. F., Gribble, J., Cooley, P., & Paone, D. (2002). The differential effects of face-to-face and computer interview modes. *American Journal of Public Health, 92*(2), 294–297.

Olsen, J. B. (1990). Applying computerized adaptive testing in schools. *Measurement and Evaluation in Counselling and Development, 23,* 31–38.

Perrin, D. (2003). Progression analysis (PA): Investigating writing strategies at the workplace. *Journal of Pragmatics, 35*(6), 907–921.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12,* 61–86.

Powell, M. B., Wilson, J. C., & Hasty, M. K. (2002). Evaluation of the usefulness of 'Marvin': A computerized assessment tool for investigative interviewers of children. *Computers in Human Behavior, 18,* 577–592.

Powell, M. B., Wilson, J. C., & Thomson, D. M. (2002). Eliciting children's recall of events: How do computers compare with humans? *Computers in Human Behavior, 18*(3), 297–314.

Preckel, F., Thiemann, H (2003). Online- versus paper-pencil version of a high potential intelligence test. Special issue: *Studying the Internet – A challenge for modern psychology. Swiss Journal of Psychology – Schweizerische Zeitschrift fuer Psychologie – Revue Suisse de Psychologie, 62*(2), 131–138.

Revicki, D. A., & Cella, D. F. (1997). Health status assessment for the twenty-first century: Item response theory, item banking and computer adaptive testing. *Quality of Life Research, 6,* 595–600.

Rosenblum, S., Parush, S., & Weiss, P. L. (2003a). The in air phenomenon: Temporal and spatial correlates of the handwriting process. *Perceptual and Motor Skills*, *96*(3), 933–954.

Rosenblum, S., Parush, S., & Weiss, P. L. (2003b). Computerized temporal handwriting characteristics of proficient and non-proficient handwriters. *American Journal of Occupational Therapy*, *57*, 129–138.

Rouet, J. F., & Passerault, J. M. (1999). Analyzing learner-hypermedia interaction: An overview of online methods. *Instructional Science*, *27*, 201–219.

Schellens, T., & Valcke, M. (in press). Collaborative learning in asynchronous discussion groups: What about the impact on cognitive processing? *Computers in Human Behavior*.

Shapka, J. D., & Ferrari, M. (2003). Computer-related attitudes and actions of teacher candidates. *Computers in Human Behavior*, *19*, 319–334.

Shimoda, T. A., White, B. Y., & Frederiksen, J. R. (2002). Student goal orientation in learning inquiry skills with modifiable software advisors. *Science Education*, *86*(2), 244–263.

Singleton, C., Horne, J., & Thomas, K. (1999). Computerised baseline assessment of literacy. *Journal of Research in Reading*, *22*(1), 67–80.

Smith, B., Alvarez-Torres, M. J., & Zhao, Y. (2003). Features of CMC technologies and their impact on language learners' online interaction. *Computers in Human Behavior*, *19*(6), 703–729.

Swanson, H. L., & Beebe-Frankenberger, M. (2004). The relationship between working memory and mathematical problem solving in children at risk and not at risk for serious math difficulties. *Journal of Educational Psychology*, *96*, 471–491.

Sweller, J. (1999). *Instructional design in technical areas*. Camberwell, Australia: ACER Press.

Thompson, L. F., Meriac, J. P., & Cope, J. G. (2002). Motivating online performance: The influences of goal setting and Internet self-efficacy. *Social Science Computer Review*, *20*, 149–160.

Traynor, P. (2003). Effects of computer-assisted-instruction on different learners. *Journal of Instructional Psychology*, *30*, 137–143.

Troia, G. A., & Whitney, S. D. (2003). A close look at the efficacy of Fast ForWord language for children with academic weaknesses. *Contemporary Educational Psychology*, *28*(4), 465–494.

van Daal, V. H. P., & Reitsma, P. (2000). Computer-assisted learning to read and spell: Results from two pilot studies. *Journal of Research in Reading*, *23*, 181–193.

Varnhagen, C. K., & Digdon, N. (2002). Helping students read reports of empirical research. *Teaching of Psychology*, *29*(2), 160–165.

Venkatesh, V., Morris, M. G., & Ackerman, P. L. (2000). A longitudinal field investigation of gender differences in individual technology adoption decision-making processes. *Organizational Behavior & Human Decision Processes*, *83*, 33–60.

Vispoel, W. P. (2000). Reviewing and changing answers on computerized fixed-item vocabulary tests. *Educational and Psychological Measurement*, *60*(3), 371–384.

Wainer, H., & Dorans, N. J. (2000). *Computerized adaptive testing: A primer*. Mahwah, NJ: Erlbaum.

Waters, G. S., & Caplan, D. (2004). Verbal working memory and on-line syntactic processing: Evidence from self-paced listening. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, *57*(1), 129–163.

Weizenbaum, J. (1976). *Computer power and human reason*. San Francisco: Freeman.

White, B. Y., Shimoda, T. A., & Frederiksen, J. R. (1999). Enabling students to construct theories of collaborative inquiry and reflective learning: Computer support for metacognitive development. *International Journal of Artificial Intelligence and Education*, *10*, 151–182.

Winne, P., Gupta, L., & Nesbit, J. (1994). Exploring individual differences in studying strategies using graph theoretic statistics. *Alberta Journal of Educational Research*, *40*(2), 177–193.

Winne, P., Hadwin, A., Nesbit, J., Kumar, V., & Beaudoin, L. (2004). *gStudy: A toolkit for developing computer-supported tutorials and researching learning strategies and instruction (version 1.0)*. Burnaby, BC: Simon Fraser University.

Winne, P. H., & Jamieson-Noel, D. (2002). Exploring students' calibration of self reports about study tactics and achievement. *Contemporary Educational Psychology*, *27*(4), 551–572.

Winne, P. H., Jamieson-Noel, D. L., & Muis, K. (2002). Methodological issues and advances in researching tactics, strategies, and self-regulated learning. In P. Pintrich & M. Maehr (Eds.), *Advances in motivation and achievement: New directions in measures and methods* (vol. 12, pp. 121–155). Greenwich, CT: JAI Press.

Xing, D., & Hambleton, R. (2004). Impact of test design, item quality, and item bank size on the psychometric properties of computer-based credentialing examinations. *Educational and Psychological Measurement, 64*(1), 5–21.

Zhang, P., & Li, N. (2004). An assessment of human-computer interaction research in management information systems: Topics and methods. *Computers in Human Behavior, 20*, 125–147.