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# Reflections on the State of Educational Technology Research and Development

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## Abstract

In this article, I comment on the 7 articles that appeared in the special issues of ETR&D (1998, 46(4); 1999, 47(2)) and an associated AERA symposium, as well as other selected developments in educational technology, as presented in a recent edited volume (Jacobson & Kozma, in press). I address the importance of the research and development described in these articles and identify 5 inter-connected themes that cut across many of them: the centrality of design, the enabling capabilities of technology, collaboration with new partners, scaling up of projects, and the use of alternative research methodologies. Together, the projects described in these articles are defining new directions for educational technology that put it at the forefront of educational research and development. At the same time, I direct a critique and challenge to traditional instructional system design (ISD) technology programs.

## Importance of Educational Technology R&D

There was a time when educational technology research was on the periphery of the more general body of research in education. Educational technology research was conducted by a relatively small, close-knit group of scholars who were focused on a fairly narrow range of issues, such as sequencing of instruction, learner control, and feedback. The design of instructional systems was the major focus of this community; media and technology were not (Clark, 1983). At the same time, educational technology development was shaped by narrow client concerns and driven by esoteric design models (Reigeluth, 1983). The narrowness of this focus minimized the impact that educational technology research had on the larger education research and practice communities.

Educational technology research and development is no longer on the margin or in the backwater of educational research. The *ETR&D* special issues demonstrate that this research is now at the center of some of the most creative, original, and powerful work in education today. The projects described here and elsewhere (Jacobson & Kozma, in press) are not minor interventions of a mere 30 minutes or even an hour, as in past IT studies (Clark, 1989). They are major projects--significant in both complexity and scope--that tackle some of the most challenging problems and explore some of the most important theoretical issues in education today.

Among the difficult educational problems that these projects address are the learning of challenging topics in mathematics and science. The curricular foci of the projects include algebra (Corbet, Koedinger, & Anderson, 1999), biology (Linn, Shear, Bell, & Slotta, 1999, Jacobson & Archodidou, in press; Horwitz & Christie, in press), chemistry (Kozma, in press) and physics (White & Frederiksen, in press). They target advanced topics in these areas, topics such as genetics (Horwitz & Christe, in press), Newtonian physics (White & Frederiksen, in press) and calculus (Roschelle, Kaput, & Stroup, in press). They support the learning of advanced cognitive processes, such as problem solving (Schwartz, Brophy, Lin, & Bransford, 1999), design (Resnick, 1998) and scientific investigation (Linn, Shear, Bell, & Slotta, 1999; White & Frederiksen, in press; Jackson, Krajcik, & Soloway, in press; Means & Coleman, in press). They target learner populations that have traditionally failed in academic subjects, such urban middle school students (Horwitz & Christe, in press; White & Frederiksen, in press; & Roschelle, Kaput, & Stroup, in press). And they test a variety of advanced technologies including artificial intelligence (Corbet, Koedinger, Anderson, 1999), networking (Shneiderman, Borkowski, Alavi, & Norman, 1998), virtual reality (Dede, Salzman, Loftin, & Ash, in press), virtual communities, visualization and modeling, and hand-held computers (Pea, Tinker, Linn, Means, Bransford, Roschelle, Hsi, Brophy, & Songer, 1999). They take on challenging tasks related to scaling-up and nation-wide implementation, such as teacher professional development (Corbet, Koedinger, & Anderson, 1999; Shneiderman, et al. 1998), cross-sector collaboration (Linn, et al., 1999; Pea, et al., 1999), and commercialization (Resnick, 1998; Pea, et al., 1999). And these articles explore deep theoretical issues related to scaffolding and knowledge integration (Linn, et al., 1999), visualization and the formation of mental models (Pea, et al., 1999; Dede et al. in press; Horwitz & Christe, in press; White & Frederiksen, in press; Kozma, in press), and technological support for problem solving (Schwartz, et al., 1999; Corbett, Koedinger, & Anderson, 1999).

I believe no other area of research in education is now as productive and intellectually stimulating as that related to educational technology R&D. The reason that this research is so vital and vibrant is that it combines design with advanced technologies, new collaborations, large-scale implementation, and alternative research methodologies. I explore each of these themes in the following sections.

## The Role of Design in Educational Technology R&D

Design has long been a core theme in educational technology R&D. Richey (1998) and Dirscoll and Dick (1999) carry on this tradition. However, many of these projects extend the design process beyond the generation of instructional materials by instructional designers to engage new groups of people in the design of new artifacts. For example, Schwartz and his colleagues (Schwartz, Brophy, Lin & Bransford, 1999) take a constructivist approach to the design process and use it to teach problem solving, to engage college students in the design of instructional products, and to help them understand academic content. They have developed an adaptable model of instructional design (*STAR Legacy*) that embeds a problem-solving cycle in a software environment, makes it explicit, and engages students in its iterative use. With *STAR Legacy*, college students enrolled in an educational psychology course are presented with a series of academic challenges and then they are guided through a process in which they generate ideas, view the challenges from multiple perspectives, conduct research, test their knowledge, and then go public with their solutions. Not only do students learn educational psychology concepts and principles from this environment but they use it, in turn, to produce instructional products that they leave behind as a legacy for students who take the course subsequently.

Resnick (1998) and his colleagues create a number of digital manipulatives that they use to engage young students in the process of design and experimentation. Resnick's team has created such playful inventions as *LEGO-Logo, the Programmable Brick, Crickets, Bitballs, Digital Beads, and Thinking Tags*. These toy-like tools have built into them a variety of student-programmable microprocessors and sensors. With these toys, students have created and programmed robotic creatures that move around, communicate, and change each other's behavior. Students have built their own scientific instruments and used them to conduct experiments, such as studies of the feeding habits of birds. They have programmed *Thinking Tags* so that when groups of students wear them, the *Tags* interact with each other in ways that enable students to study how diseases are spread. The students program *Bitballs* to send acceleration data to a music synthesizer in real time, so they can "hear the motion" of the ball as they throw it in the air.

Jackson, Krajcik, and Soloway (in press) have developed a model-building software program called *Model-It* to engage students in project-based learning and scientific investigation. In the course of these activities, students use the software to build dynamic, computational models of scientific phenomena and run simulations with these models to analyze and verify the results of their investigations.

Sneiderman and his team (Sneiderman, Borkowski, Alavi, & Norman, 1998) support university professors in designing computer-based activities for the courses that they teach. Sneiderman's team provides these professors with a set of "lectureware" tools that they can use to design and assemble activities for courses that they conduct in computer-enriched classrooms. These tools include the *One Minute Paper* (a way for instructors to receive, review, and electronically display brief student responses to a problem), the *Feedback Meter* (a way for students to electronically indicate whether they are following a lecture or are confused), and *MultiChat* (a tool to support on-line discussions). These resources and classroom activities have resulted in significant changes in faculty teaching, moving them from a style predominated by stand-up lecture to classes that emphasize active individual learning, small-group learning, and entire-class collaboration.

All of these projects are using technology to take design beyond the exclusive domain of the instructional designer and engage adults and children, teachers and students in the design process. The projects are opening up the design process, making it explicit, and making it accessible to others. As a result, users are learning not only academic content but learning how to use technology to design solutions to problems they encounter in their everyday world.

## The Role of Technology in Educational Technology R&D

Technology–principally computer-based technology–played a central role in many of the articles that appeared in the special issues and other articles that I examine here. In some cases, a particular design was possible only because it employed the unique capabilities of the technology. In other cases, the ubiquitousness of technology is assumed and "low-tech" activities such as library searches, reading, and writing are embedded into a software environment that integrates these activities and structures the way they work together to support learning.

Many of the projects were possible only because the powerful processing capabilities of computers enabled their designs (Kozma, 1991, 1994). For example, the design activities that Resnick (1998) created for young children were possible only because of the sensory, control, and infrared communication capabilities that were built into his digital manipulatives. The ability of *Thinking Tags* to be programmed and to communicate with each other makes it possible for Resnick to design activities in which students explore the spread of diseases. The ability of *BitBalls* to sense motion and to send this information to other devices in real time allows Resnick to design activities in which students can explore the relationship between acceleration and motion as an auditory experience.

The ability to model student knowledge and customize activities and feedback that is built into the Algebra I Cognitive Tutor (Corbett et al., 1999) is possible only because of advanced artificial intelligence capabilities. With this project, the authors used learning theory (Anderson & Lebiere, 1998) and the processing capabilities of the computer to design a program that monitors and models students' problem solving activity–a process called model tracing–and uses this information to provide customized step-by-step feedback and context-specific advice.

Other designs were possible only because they were able to employ novel symbolic capabilities of computers, particularly as symbolic elements are connected to the computers processing capabilities (Kozma, 1991). For example, Dede and his colleagues (Dede, Salzman, Loftin, & Ash, in press) created a virtual reality environment in which students could navigate through a protein molecule or "become" a moving ball in a Newtonian universe. This design was possible only because the symbolic and processing capabilities of the computer enable the designers to generate a representation of an otherwise unobservable protein molecule and allow the students to navigate through this molecule. Often in these projects, phenomena that are represented in one way are computationally connected to other representations of the same phenomena in ways that allow students to understand the phenomena through both representations together. For example, with GenScope (Horwitz & Christe, in press) students see the effects of genetic change represented at five levels: DNA, chromosome, organism, pedigree, and population. At each level, students can symbolically operate on the underlying genetic model and see what happens to a fictional species of dragon. These features allow students to make changes at the DNA and see what happens at an organism level, for example, or make changes at a chromosome level and see what happens at a population level. Similarly, the *4M:Chem* software developed by Kozma's team (in press) allows students to conduct a simulated chemistry experiment and see what it looks like at both a physical and molecular level. These designs are possible only because of the symbolic and processing capabilities of the computer.

With other projects, the power provided by the technology is more subtle. For example, in the *STAR-Legacy* problem-solving environment developed by Schwartz et al. (1999), much of what the student do is read, listen, and watch as they navigate through text and video segments. They also consult resources and write. With the *Knowledge Integration Environment* (*KIE*), developed by Linn and her team (Linn et al., 1999; Slotta & Linn, in press), students read articles, examine photos, and conduct in-class debates related to the "Deformed Frogs" controversy and other science controversies. Similarly, Jacobson and Archodidou (in press) have created the *Knowledge Mediator Framework* in which students explore multimedia cases related to evolution, natural selection, and adaptation.

There is no motion sensing or model-tracing going on here. Many of the activities that students do in these environments are ones that can and often do occur in classrooms that do not use computers. For the most part, the computational capabilities of computers that these designs draw on are rather modest.

The advantage that the computer provides is the integration of resources and the structuring of activities that support learning. With *KIE* (Linn, et al., 1999; Slotta & Linn, in press), students can search the web, view photos, read documents, express their ideas, and interact with scientists, teachers and other students all in the same environment. In addition to the practical efficiency of this arrangement, the design uses the computer's capabilities to support student learning by prompting the students to be reflective about the sources that they read, their thinking, and their discourse. Similarly with *Evolution Knowledge Mediator* (Jacobson & Archodidou, in press), the computer supports learning by making explicit the underlying cognitive structure of these resources. In both cases, this support is made possible because both the resources and the students' activities are integrated into the same computational space. These computational capabilities provide designers with a pallet of powerful tools that enable new designs that were not otherwise possible.

## Collaboration with New Partners

Another theme that cut across many of these projects was the range and depth of collaborations that were formed. Partnership was the theme of the Linn et al. (1999) paper. As Linn points out, "Successful partnerships involve long-term collaborations between experts in all relevant disciplines, including classroom teaching, natural science, technology, curriculum, assessment, and pedagogy" (p. 62). These partnerships guide the design specifications. The group engages in an iterative process in which members construct novel approaches to meet the needs of the group; they select criteria for success, and they test these innovations in the classroom.

The composition of the partnerships in these projects varies with context , scope, and need. In the Corbett project (Corbett, et al. 1999), the Algebra tutor was developed in collaboration with a mathematics teacher. With the Kozma (in press) project, the *4M:Chem* environment was developed and refined in partnership with a chemistry professor and tested in chemistry courses over a period of 10 years. White and Frederiksen (in press) worked in urban classrooms over a 7-year period to develop *Thinker Tools*, a software environment to make physics and scientific inquiry accessible to a wide range of students. The GLOBE (Global Learning and Observations to Benefit the Environment) program, evaluated by Means and Coleman (in press), is a collaboration between the scientists and staff members at the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administrations, the National Science Foundation, the Environmental Protection Agency, and the Departments of Education and State as well as participating university researchers and educators. The goal of the project is to develop software, scientific protocols, and curriculum materials that allow students to collect scientifically accurate local data on air, water, and flora and share these with scientists and other students using the Internet.

Perhaps the most ambitious collaborative project is the NSF-funded, national Center for Innovative Learning Technologies (CILT), directed by Pea and his colleagues (1999). CLT is specifically established to mobilize the multiple cross-sector collaborations and partnerships that are needed to stimulate research and development of technology-related solutions to critical problems in K-14 science, math, engineering, and technology learning. First of all, the Center is itself a distributed, virtual center composed of researchers from SRI International, the University of California Berkeley, Vanderbilt University, and the Concord Consortium. Their charge is to create a web of organizations, individuals, industries, schools, foundations, and government agencies and labs that would work together to produce, share, and use new knowledge and technology to improve learning and teaching. These collaborations span four areas of research and development: visualization and modeling, models of technology and assessment, low-cost computing, and tools for learning communities.

The collaborative arrangements described in the papers break the mold of the single researcher collecting data to confirm or refute the validity of his or her latest theory, model, or design. They go beyond the model of narrow designer-client collaborations. These collaborations and partnerships are bridging institutions, organizations, sectors, and disciplines to bring together a coordinated set of resources to design technology-based environments that solve problems of teaching and learning.

## Scaling Up R&D Projects

In 1989, Clark bemoaned the state of research in education technology citing the fact (among others) that the mean length of interventions used in IT research was about an hour. Too often, educational technology researchers have relied on convenience samples of college undergraduate students for their studies. Treatments have been prototypes designed to test a favored model or medium.

The projects described in the articles I reviewed have advanced the practice of educational technology research and development to go beyond these limitations in scale. Shneiderman and his colleagues (1998) have worked with 74 faculty members in over 260 courses to affect over 7,500 college students. Corbett and his colleagues (1999) have implemented their materials in 75 schools in 9 states to affect over 8,000 high school students. Resnick (1998) and his colleagues developed *Lego-LOGO* and through the cooperation of a toy manufacturer the materials were used by over 20,000 elementary students. The GLOBE program (Means & Coleman, 1999) has been implemented in over 4,000 schools in 55 countries.

In the course of scaling up the R&D effort, these researchers have had to address a plethora of complex practical problems and issues. Among them, were issues related to adjusting materials to fit the emerging standards of external agencies, technical support and maintenance of facilities, professional development, and commercialization. Rather than treating these issues as messy intrusions into their theories or models or unnecessary noise in their research designs, these researchers have considered them as a core part of the real-world context. The researchers have begun to address these complexities both in their design practices, theories, and research.

## Alternative Research Methodologies

As both Richey (1998) and Discroll and Dick (1999) point out, the messy, uncontrolled context of real-world educational technology R&D demands alternative research methodologies. Traditional experimental designs are often not able to accommodate the complexity of these real-world situations. Driscoll and Dick list a variety of research approaches that can enrich the IT researcher's repertoire. They include case studies, surveys, program evaluation, developmental research, and qualitative-naturalistic empirical approaches.

The bulk of the projects that I reviewed would benefit from the approaches recommended by Driscoll and Dick. These were complex situations that were naturally and intentionally confounded. Curriculum was changed to take advantage of the technology. Technology was used as part of the assessment. Teachers were trained on both the operation of the hardware and software and its integration into their teaching. This confounding makes it difficult, if not impossible, to disentangle one component of a design from another because the various components are designed to work together. These confounds violate assumptions built into the traditional experimental design model. Alternative methods, used either individually or in combinations, can over come some of the limitations of the traditional experimental approach to help researchers understand what is working, what is not working, why it is working or not, and what can be done about it.

Several of the articles that I reviewed describe projects and efforts that are not yet ready to be tested. Others present results. Some of these studies used rather traditional experimental research designs to examine impact. For example, Crobett et al. (1999) compared students using the *Algebra I Cognitive Tutor* with students in a traditional Algebra course to find that the *Cognitive Tutor* students showed nearly 100% improvement on items that tested higher-order reasoning skills, significantly higher than the control group. White and Frederiksen (in press) tested middle-school children who had used *Thinker Tools* and found that they made significant gains from pre- to post-tests and scored significantly higher on post-tests than did high school physics students who were taught using traditional methods.

Others studies, however, used one or more alternative approaches. Jackson et al. (in press), for example, followed 100 ninth-grade students over the course of the school year, as they used *Model-It* to conduct investigations. They collected a variety of alternative data such as video and audiotapes of investigation sessions, post-interviews with students, and log files of student interactions with the computers. They found that over time students moved from building simple models of the phenomena they studied, to building more complex models that demonstrated an in-depth understanding of the phenomena. White and Frederiksen (in press) supplemented their examination of test scores to look at how students conducted a performance task where they designed and conducted an experiment. Again, *Thinker Tools* students outperformed control students.

Means and Coleman (in press) conducted an analysis of archives of the electronic discourse among participants in the GLOBE program and showed how the computer-enabled activities and human resources combined to help students become enthusiastic partners in the generation and interpretations of scientific data. Both Kozma (in press) and Roschelle et al. (in press) used face-to-face discourse to document the impact of features and functionality of their respective learning environments on student reasoning and understanding.

These alternative approaches to research on learning environments hold promise for providing us with a deeper understanding of how the systems work, for determining which features have which effects, and for understanding the contexts of their use.

## The State of Traditional ISD

I do not mean to ascribe all 5 themes to each of the articles that I have reviewed; there is a range across them. Design is central to many of them but some emphasize enabling technologies others emphasize new partners; yet others focus on scaling. The work of Corbet, Koedinger, Anderson (1999) on cognitive tutors in Algebra is very different than Linn's (Linn et al., 1999; Slotta & Linn, in press) work on her integrated knowledge environment. Shneiderman's (Shneiderman, et al., 1998) work with faculty at the University of Maryland is very different than Resnick's (1998) work with children. These projects work in different contexts, address different content domains and learner populations, and use different theories, or for that matter are relatively more or less theoretical. Clearly, educational technology research is not monolithic. In fact, this is part of its vitality.

However, there are two papers in the *ETR&D* special issues that clearly fall in a separate category from the rest. These are the papers by Richey (1998) and Driscoll and Dick (1999). The overlap between these two papers characterizes what could be called the traditional instructional systems design (ISD) paradigm. The differences between these two and the other papers was apparent both in reading the them and listening to and watching their presented versions at AERA. These similarities and differences raise significant concerns about the future viability of the ISD paradigm and educational technology as a field.

First, both Richey's (1998) and Driscoll's and Dick's (1999) papers were very inwardly focused. By this I mean that both papers were narrowly focused on the models, literature, and practice of instructional technology. Some of this was due to the charge that structured the special issues; the issues were loosely organized around emerging research issues in the field. But in reflecting on one's discipline, it is important to draw on closely related and even distally-related disciplines to both inspire new ideas and sharpen boundaries. Cross- and inter-disciplinary thinking characterized the bulk of the other papers I examined in which projects drew on deep understanding of and current developments in cognitive psychology, developmental psychology, computer science, and sometimes even the natural sciences. The references cited by these articles were from a range of sources that included the *Journal of the Learning Sciences, Communications of the ACM, American Journal of Physics, Journal of Chemical Education, Interactive Learning Environments, Journal of Science Education and Technology, and Cognitive Science.* By contrast, over 70 percent of the citations in the Richey (1998) and Driscoll and Dick (1999) articles were from *Educational Technology, Journal of Instructional Development, Journal of Educational Technology Systems, Performance and Instruction, Educational Technology Research and Development,* AECT conference presentations, or dissertations from an IT department. Both articles spent a significant amount of effort carefully coding, counting, and analyzing articles from back issues of *ETR&D*. This over-introspection reduces the likelihood that new ideas will emerge in the field. If anything, the authors of these two articles seemed to invite an even narrower focus for IT research, despite their statements otherwise. Richey (1998) claimed that "the most useful research is that which directly addresses our own problems" (p. 19). Both articles called for systematic research on instructional designers and the instructional design process that included a focus on such design components as rapid prototyping, task analysis and electronic performance support tools. A discipline that draws on its own practices as the primary inspiration of its research and theory risks stagnation and decline.

Second, both articles were excessively backward focused. In most of the articles I reviewed here, the bibliographies are filled with references that are less than 5 years old and peppered with occasional "in press" citations. Many of these articles built on and extended contemporary constructivist theories or they forged new theories to support their designs or account for their results. In contrast the theoretical touch stones for Richey (1998) and Driscoll and Dick (1999) were at least 15 years old. Conceptual models from Dale (1946), Finn (1953), and Briggs (1982) were used as the foundation for thinking about the present and future of the field. The bygone theories of Gagné and Skinner are wistfully mourned with hopes that someone will come up with theories of "equal specificity" to take their place. For example, Driscoll and Dick (1999) suggest that no new research paradigms in IT are unnecessary if only we draw on Briggs's 1984 conceptual framework where he proposes that IT research center on systematically designed curriculum materials (what Briggs calls "Culture Four" research). Contemporary constructivist theories are dismissed as vague or of little use (Driscoll & Dick, 1999).

The early theorists in educational technology made significant contributions to the field and these contributions need to be acknowledged. My own dissertation work (Kozma, 1972) at Wayne State was based on Gagné's (1970) theories. But the field will have no future if our researchers do not see ways of pushing the boundaries of thinking and moving them forward. Dale, Finn, Briggs, and Gagné do not hold the keys to the future of educational technology.

Third, although Richey (1998) calls for research that is useful to practitioners, there is a fundamental disconnection between the ISD field and the practitioner communities that it seeks to support. While Linn (Linn et al., 1999; Slotta & Linn, in press) forms new partnerships with teachers and researchers to change science classrooms and Corbet and colleagues (Corbet, et al., 1999) collaborate with teachers to co-design new materials, Richey wants to conduct studies in natural settings <u>using</u> subjects in their natural roles and Driscoll and Dick (1999) want to "obtain permission to collect data from students for research purposes" (p. 15). The traditional ISD research community sees itself in control of the design process. There is a sense in which "we do it and you use it" and then "we will study your use of it" (or worse yet, "we will study how we do it"). But collaboration is not obtaining permission to collect data in schools. A partnership is not achieved by having researchers "attune their agendas to practitioner needs" and having "practitioners become better readers of research". Partnerships are formed by extended collaboration, and collaboration, in turn, results from engaging others in a process that is a synthesis of the needs, goals, skills, and experiences of both communities. Schwartz and colleagues (Schwartz et al. 1999) and Resnick (1998) open the design process and let students and teachers create their own designs. They want the design process to be appropriated by the user community; they want to let go of it and give it away. They influence and facilitate design by developing tools that enable these users to create designs that meet their needs. Both design and research become embedded in the activities of the community. These projects are true collaborations in which the products of design are the synthesis of multiple views, skills, and experiences. Research is valued because the user community co-owns the process and products it produced, not because the findings that outside researchers produce are "useable."

Finally, neither Richey (1998) nor Driscoll and Dick (1999) address fundamental issues about the role technology and media play in learning and instruction. Ironically, it was the non-traditional educational technology researchers who were using the powerful capabilities of technology to inspire and enable their designs and research. This was most apparent at the AERA symposium. The work of Corbett, Pea, Shneiderman, Resnick, and Schwartz drew heavily on technology; these authors literally could not discuss their research without using computers and multimedia in their AERA presentations. Richey and Driscoll used overhead transparencies. The field of IT long ago gave up on the role of media and technology as a theoretical focus for research in the field (Clark, 1983). Others have taken up the challenge and filled the vacuum. Without thinking deeply about the role that media and technology play in enabling designs and influencing teaching and learning, the field of educational technology will wither.

Ten years ago, Reigeluth (1989) stated that the field of educational technology was at a crossroads. "Increasingly," he said, "educational technologists find ourselves on the sidelines in our own ballgame" (p. 67). This is still the case, I am afraid, and it will continue to be so unless there are fundamental changes in the field. I disagree strongly with Driscoll and Dick (1999) when they claim that new research paradigms are unnecessary in educational technology, that we need merely to increase funding or the time available for faculty research or employ younger faculty members who have more energy and more contemporary methodological skills. I do not agree that we need merely to rededicate ourselves to Briggs's Culture Four. By their own analysis, Driscoll and Dick demonstrate that this approach has not spawned the research productivity you would expect of a robust paradigm. Perhaps it is the paradigm rather than the researchers or the user community that needs to change. I contend this is so if we are to become major players in our own game.

I believe we need to make fundamental changes in the way we think about practice, theory, research, and development in our field. Perhaps it is useful to build on Briggs's terminology and say that we need to build a Fifth Culture, because I think the transformation we must make is at the level of creating a new culture. I do not claim to have the answer for the new things we must do and the new ways we must think. No single person does; all cultural change emerges from discourse and action within the community as a whole. But I would like to take an initial position and challenge the rest of the community to take up the discourse.

There are three components to my proposed cultural changes that draw on the articles I reviewed and that roughly parallel the three components proposed by Driscoll and Dick (1999): context, learning outcomes, and materials. First, I would like to go beyond Richey's recommendations for building perceptions of research utility to suggest that we need to reconceptualize our relationships with our clients. We need to do more than embed our research designs in the "real world"; we need to embed ourselves in the contexts of our client base. We must come to deeply understand their needs, goals, problems, and issues and embed these, in turn, into our theories, research, and practices. This is a multi-disciplinary undertaking. We need to understand their latest theories, research, and issues of practice, in whatever context domain we chose to work, whether it is in support of learning in the middle school science classroom, the auto manufacturing industry, or higher education. If we are designing solutions for learning high school chemistry, for example, we must understand chemistry, the difficulties students have in learning it, and the problems teachers have in teaching it. We must develop sustained relationships with our clients over a period of years that allow us to understand this context and integrate it into our work. We should read the journals they read, go to their conferences, intern our graduate students in (and recruit from) their organizations, relate to them as colleagues, and co-design solutions to their problems. Perhaps our doctoral students should be required to come into the program with a Master's degree in a substantive area (such as chemistry or literature) or experience in a field of practice (such as teaching, sales, or production management). Perhaps they should be required to declare a minor in a substantive discipline and do their dissertation work in that area (such as a minor in science education or chemistry and a dissertation on the impact of learning environments on students' understanding of chemistry). Perhaps our junior faculty members should be encourage to develop a substantive focus, as well as a focused research agenda. Perhaps our senior faculty members should be encouraged to collaborate with their colleagues in the college of arts and sciences or business administration, to read broadly, and to join disciplinary associations in addition to AECT or AERA (such as the National Association for Research on Science Teaching or even the American Chemical Society). These multidisciplinary measures will create a new culture and bring new people and ideas into our field. As a result our designs, research, and theories will of necessity be more thoughtful and more sensitive to the context of their use. I believe that it is in this way that our research will be vital, relevant, and useable.

Second, we need to shift the focus of our work from the design of instruction to the design of learning environments. This is not just a shift from content- to learner-focused instruction. It is an acknowledgement that learning outcomes are owned by learners. People are in charge of their own learning, whether they are teachers or students, adults or children. It is a shift in mind set: we do not set the objectives for learning, they do. And these objectives emerge, change, and develop over time. Learners are also in charge of arranging—of designing—the context for their learning that works for them. Our goal should be to provide them with the tools and resources that get them where they want to go, that empower them to do what they want to do. If learners are not yet skilled in taking charge of their own learning, our tools and environments should help people move in that direction. I believe this is the appropriate learning outcome of our work. As learners use these designs, they should become more masterful in choosing their own goals, constructing their own strategies, assessing their own knowledge, and monitoring their own progress. This shift will have significant implications for our research designs, for different learners will go in very different directions and end up learning very different things. Alternative research methodologies will be mandatory; indeed, we will probably need to invent new ones.

Finally, however much we open up the design process, we are still participants and prime contributors. The design of learning materials and environments is the core of our field. However collaborative the process is, we bring a unique set of skills, knowledge, and experience to bear on the designs. The materials and environments that we design are expressions of our individual and collective knowledge base. But like painters, sculptors, architects, and fashion designers, we express our ideas in a medium. The medium shapes the way we think and what we do; it both enables and constrains the designs we create.

If we understand the media we use, they can inspire our creativity and enable powerful designs. Understanding the relationship between media, design, and learning should be the unique contribution of our field to knowledge in education. This understanding is the base of our practice and our theory and our research. But if we chose to continue to ignore media considerations in our thinking, if we continue to treat them as mere delivery devices, both our thinking and our field will be impoverished. Our future will be doubtful and others will take our place.

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