The Learning Sciences: Past, Present, and Future

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How can we accurately define the differences between Instructional Systems Design and the Learning Sciences? I can't tell you for sure, mostly because I am another one of those people who couldn't pass an Instructional Systems Design qualifier if my life depended on it. On the other hand, I've been Editor in Chief of the *Journal of the Learning Sciences* since its inception, was a founder of the International Society of the Learning Sciences (ISLS; www.isls.org), and am Executive Officer of that organization. So I have a pretty clear view of how the journal and field came to be and how they've evolved. Perhaps that will shed some light.

1 A history of the Learning Sciences

As several of the writers of the articles in this collection point out, the learning sciences got its start as a cognitive science. I remember a discussion I had with Allan Collins when I was on sabbatical in Boston during the 1987-88 academic year. I told him I was growing bored with the *Cognitive Science* journal (he had been one of its founders). Using the language of the time, I thought that the journal was publishing too many reports of "neat" research and not enough that came from a "scruffy" perspective. Allan agreed and told me that it was my generation, and maybe me, who would have to move things forward from where they were. I winced a bit.

1.1 Mid 1990's foment in the cognitive science community

Unbeknownst to me, there were cognitive scientists around the country who were equally frustrated by cognitive science of the time, all feeling that the complexity of the real world was being bypassed in much cognitive science research. The missing pieces I recognized were the complexity of the tasks being addressed and their connections with personal experience. My particular gripe was that so many researchers were focusing on toy problems such as the Towers of Hanoi where there were only a small number of things for the reasoner to decide between and where context is narrowly defined by the rules of the game and the state of the game board. In the real world, my colleagues and I argued, reasoners make decisions in situations where there are several orders of magnitude more possible choices for moving forward and where figuring out which of the huge number of ways of interpreting the situation provides the best context for reasoning. What could toy problems tell us about those situations? Others, primarily in Northern California, at Stanford, Berkeley and Xerox, were concerned that the social and physical worlds were being ignored in cognitive science research. Cognitive science was focusing on what was in the head and forgetting that people reason and learn through interactions with physical objects and with each other. For example, why is the reasoning that people do in

real-world situations often so different from what they are taught to do in school? These researchers also asked about where the processes and representations reside if our interactions with others are playing major roles in our abilities to be successful and if our discussions with others play big roles in our learning. Cognitive science of the time wasn't addressing these issues, nor were its methodologies – protocol analysis, computational modeling, and the traditional methodologies of linguistics and psychology – appropriate for finding answers to these questions. Not surprisingly, it was cognitive scientists working on issues in education and workplace performance, those who repeatedly encountered the differences between what our theories of cognition were telling us and what was actually happening in the world, who were most vocal about cognitive science's narrow focus of the time.

1.2 Mid 1990's foment in related research communities

At the same time, researchers in educational psychology, cognitive science, and artificial intelligence were frustrated by the narrow focus of the AI in Education community, the community most focused on sophisticated educational uses of software. They thought we should do better in our designs of software for learning than building intelligent tutoring systems. Seymour Papert and his colleagues had been working on Logo as a programming language for learning about all kinds of things, but primarily elementary math; Andy diSessa had been working on Boxer as a programming environment for exploring physical phenomena; Alan Kay had been working toward his DynaBook, an electronic general-purpose environment to support education for many years; folks like Rick Duschl, Bob Glazer, Barbara White, Alan Lesgold, and their colleagues were designing microworld software environments for modeling and simulating real-world environments and getting feedback; folks like Roy Pea, Jan Hawkins, and Rich Lehrer (and their colleagues) were exploring a myriad of uses of hypertext, word processing, and other general-purpose software programs in support of learning. Still others, like Ann Brown and Joe Campione; John Bransford, Susan Goldman, and Jim Pelligrino; and Allan Collins and colleagues were focusing attention on what could happen in classrooms to promote deep and lasting learning, at least partly with the idea of finding out what computers might be good for in education. Marlene Scardamalia and Carl Bereiter were just beginning to take their research on writing and use it to inform the creation of software that could help people learn to be writers. And so on. These folks were publishing in the science education, artificial intelligence, and cognition and instruction literatures. It made sense to some of us to join their efforts with those of the cognitive scientists referred to above and have a cognitive science venue where they could share what they were learning about promoting learning with others with similar interests. Roger Schank had just started the interdisciplinary Institute for the Learning Sciences at Northwestern and was gathering together many of the best cognitive scientists interested in learning to work together at the full range of research on learning and promoting learning with computers; Xerox had just spun off the Institute for Research on Learning, also an interdisciplinary institute, this one carrying forward the situated view of learning alluded to above and focusing on methodologies for studying reasoning and learning in real-world situations (e.g., interaction analysis (Jordan & Henderson, 1995); and Vanderbilt's Center for Learning and Technology was applying what we know from cognitive science to creating technology-based curriculum materials aimed at promoting more deep and lasting learning than most curriculum designers had aimed for in the past.

1.3 Birth of the *Journal of the Learning Sciences*

It was within this world of intellectual foment, in 1989, that Roger Schank, Allan Collins, and Andrew Ortony asked me to found the *Journal of the Learning Sciences*. It would be a venue, they told me, where cognitive scientists of all kinds could publish articles about learning in realistic and real-world situations and about using what we know about learning in such situations to promote better learning in schools and other educational venues. In their conception, it would publish big ideas about learning and promoting learning. They told me to talk to a selection of the people who were part of this foment, find out from them what they thought was important and who they thought would want to be leaders in moving cognitive science forward in this direction, and based on that, to put together an editorial board, a statement of purpose, a call for papers, and invitations to write papers for the first volumes.

I talked to cognitive science leaders in learning and education from around the country, many of whom I had never met before and some of whom I had never heard of (my background was a cognitive modeling and AI approach to problem solving and learning in real-world situations – case-based reasoning; I knew nothing about education) – Alan Schoenfeld, Seymour Papert, Lee Shulman, Andy diSessa, Allan Collins, Jim Greeno, Bob Glazer, Rich Lehrer, and Micki Chi were only a subset of the people I talked to. Most agreed about a need for a journal devoted to learning in real-world situations; most agreed that it should be a "big ideas" journal – that it would include technology in its focus but that it would focus on making clear new perspectives on learning, new methodologies for studying learning, and novel uses of technology to promote learning. Another journal, *Interactive Learning Environments*, was just getting started as well, and there was a need to distinguish *JLS* from both that journal and *Cognition and Instruction*. *ILE*, which was ahead of *JLS* in its planning, was already planned as a technology-oriented journal, and *Cognition and Instruction* focused at that time mostly on experimental reports.

Those people suggested other folks I should talk to about the future of studying learning, folks who would be good for the editorial board, and folks who I should solicit for papers for the first volumes. They, as well as Larry Erlbaum (the publisher), gave me advice about running a journal. *If it's going to make it as an interdisciplinary journal, get reviews from people across disciplines to make sure the work is readable by a diverse audience. Your power is in the people you choose to be reviewers. Always use reviewers, even if you think a paper is not going to make it – better to blame it on reviewers when you turn down a paper than to take the blame yourself. We're going to have to use the journal to grow the community; think about ways to make that happen.* … I got an excellent education, and I moved forward to solicit manuscripts to be reviewed for the first two volumes.

Micki Chi and Kurt VanLehn had recently published their groundbreaking paper on self-explanation in *Cognitive Science*. That paper had masses of quantitative data culled from people's explanations in different situations, but it provided little detail about the actual content of those explanations. I asked them to write a paper reporting on the content of self-explanations and what kinds of content seem to promote better learning. Marlene Scardamalia and Carl Bereiter were having their first successes at using their model of the cognition involved in writing to design software and classroom strategies to promote writing that addresses an audience and the thinking that requires. I asked Roger Schank to write about his early work on using computers to support learning by doing. And so on.

The first volume of *JLS* went to press in July, 1990, and came out in January, 1991. The first two volumes reported on computational models of learning (by, e.g., Kris Hammond, Ashwin Ram, Mike Pazzani, and Kurt VanLehn), careful descriptions of development and reasoning involved in learning (by, e.g., Micki Chi, Leona Schauble, and Jeremy Roschelle); proposals, descriptions, and evaluations of software for promoting learning (by, e.g., Roger Schank and Brian Reiser), classroom studies (by, e.g., Ann Roseberry and Marlene Scardamalia), methodology for studying learning *in situ* (by, e.g., Ann Brown, Geoffrey Saxe, and Allan Schoenfeld), and, yes, a couple of traditional experimental pieces (e.g., by Dufresne). Perhaps most exciting was the special issue on methodology. Allan Schoenfeld and I talked a lot about that; it's not an ordinary thing for a research journal to publish papers about methodology, but we thought it was a necessary component of a journal that was trying to promote new ways of studying learning. The special issue he put together included Ann Brown's groundbreaking paper about design experiments (Brown, 1992). We've continued the tradition of publishing papers on methodology, including some of the most important in the cognitive and learning sciences – Micki Chi's paper on verbal protocol analysis (Chi, 1997), Gitti Jordan et al.'s on interaction analysis (Jordan & Henderson, 1995), and a whole host of papers on design studies and design experiments (see special issues in 2001 and 2004). We also continued the tradition of special issues as snapshots of important work going on in an area, with special issues devoted to computer support for collaborative learning (1993/4), goal-based scenarios (1993/4), gesture and talk in collaborative learning (1996), conceptual change (1997), authoring tools (1998), learning through problem solving (1998), learning through designing (2000), designed artifacts in math learning (2002), and, coming up in 2004, one on design studies and another on scaffolding.

1.4 Building a Learning Sciences community

Along with the journal, the learning sciences has been defining itself through conferences and workshops. The East Coast people and the West Coast people, who, up until then, weren't all aware of each other, were brought together at the first International Conference of the Learning Sciences at Northwestern in 1991. The conference was organized as part of the series of conferences in Artificial Intelligence and Education that was put on by the International AI and Education community. Roger Schank renamed it that year and, in an attempt to broaden the field, invited speakers who were part of this growing community – many of whom were the first set of authors in *JLS* – and sent the call for papers to not only those who had been targeted for that conference in the past, but also to those who were beginning to define themselves as learning scientists. The AI and Education conference, that year, focused not only on using artificial intelligence for educational applications and on what AI could teach us about learning, but also on what cognitive scientists from education schools, educational psychology departments, computer science departments, and the like could teach us about learning and its promotion in general. The AI and Education community didn't appreciate this "takeover" of their conference, and they went back to their traditional focus the following year, but this conference was a milestone for the learning sciences community. People who didn't know each other and didn't know each other's work met and talked for the first time.

The next Learning Sciences conference was held in 1996 (again at Northwestern), and there have been learning sciences conferences every 2 years since then and CSCL (Computer Support for Collaborative Learning) conferences in the years in between, most in the US, but some in Europe as well. Each has drawn between 250 and 350 attendees. Each has included a Doctoral

Consortium where leaders in the field help promising Ph.D. candidates to reflect broadly on their research. All of these conferences plus the journal have helped the learning sciences to grow its identity. Early on, many cognitive modeling people considered themselves learning scientists, but those articles stopped coming to the journal and became a smaller part of what was submitted to the conferences over time, perhaps because many of the issues needing attention in real-world learning were too hard to tackle with the kinds of modeling we knew how to do. We thought we'd get big idea articles from cognitive and educational psychologists who now had a venue for publishing those kinds of reports, but there have only been a few of those (though we'd love more). There certainly have been papers reporting on computational models and on results of experimental programmes of study, but by 1996, the majority of the papers that came to the journal were about methodology, classroom studies, careful descriptions of learning, software design, integration, and evaluation, and curriculum design, with a central focus on complexity and systemic approaches to curriculum design, understanding classrooms, teacher education, and reform. And joining the cognitive scientists who were involved from the start have been researchers focused on discovering the affordances for learning of new technologies. While the community began as a cognitive science offshoot, it includes many other kinds of researchers now, and it is no longer a subset of cognitive science.

1.5 Maturation in the decade since *JLS* was established

How has our community matured over time? I've noticed while acting as mentor in doctoral symposia and reading journal manuscripts that our understandings of how to use and get believable results from observational methodologies are becoming more sophisticated. Having expanded from being a cognitive science to being a socio-cognitive science, we've had to develop new methodologies. Ann Brown's (1992), Allan Collins' (1992), Micki Chi's (1997), and Jordan's & Henderson's (1995) seminal papers aside, it's taken some time for us to learn, as a field, to refine the proposed methodologies and learn how to apply them in ways that give us the most informative results. During the early to middle 1990's, we were exploring use of methodologies from the social sciences (e.g., ethnography), trying to apply them exactly as they were created. Many of us had learned, by the end of the 1990's, that while those methodologies worked well for describing, they weren't working as well for helping us come up with explanations of learning and of how to promote it well. We needed to adapt those methodologies to our own goals. Nowadays, most of us know that we're not simply going into situations to describe; rather, we engineer the situations as best we can based on what theoretical foundations tell us will promote good learning, we make predictions about what we will see, then we observe, using ethnographic methods for observation, and then we create and refine coding categories based on our predictions (top down) and what we see (bottom up) that can help us explain if something happens that wasn't what was predicted. We aim our observational studies at helping us explain learning phenomena, not simply describing them. Over the years, too, the studies *JLS* publishes report on situations having more and more complexity. As our investigative methodologies have evolved, so has our ability to investigate more of what has a bearing on learning.

2 The Learning Sciences as a community of practice

Since the late 1990's, we've been able to begin articulating what a "learning scientist" is and what the goals of the learning sciences are. While we are still far from full agreement on these

defining characteristics (the International Society of the Learning Sciences doesn't yet have an official definition), I'm able to draw up the characterizations below that I think come pretty close to what most in our community would agree on.

> Learning scientists harvest theories of active, constructivist, and participatory learning to design software and learning environments and ways of educating that promote deep and lasting learning. As a parallel activity, they study people's interactions and behaviors and learning in these engineered environments to learn more about both learning itself, how to promote better learning, and how to promote learning more effectively.
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> Learning sciences is the interdisciplinary pursuit of
> - Understanding what "learning for applicability" looks like – developmental trajectories, manifestations of different gradations of understanding and capability with the end product being learners who can productively use concepts, skills, and practices they are learning
> - Identifying ways of promoting deep and lasting learning – of complex skills, practices, and content; in the classroom, on the job, informally, and as part of life-long learning endeavors; in person and at a distance
> - Identifying the environmental factors (large and small) that effect how people learn – who and what need to play roles, the roles they need to play, details about enactment of those roles, and so on
> - Designing software, activity structures, curriculum materials, environments, teacher professional development, etc., to promote such learning
> - Designing methodologies for studying learning *in vivo*.
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> Learning scientists have a set of deep and abiding beliefs.
> - Learners are social animals who participate in communities and who learn by participation and active construction of mental models (learning sciences is rooted in cognitive, socio-cognitive, and socio-cultural approaches to learning).
> - Technology can help promote learning in powerful ways. To do that, it needs to be designed carefully taking the needs of learners and their whole social system and environment into account, and ways the software might be integrated into the learning environment must be considered and designed along with the software. Learner-centered design (e.g., Soloway et al., 1993) and classroom-centered design (e.g., Tabak & Reiser, 1997) provide guidelines about what to take into account in designing learning environments.
> - We need to work with those who know learning environments and learners well (e.g., teachers) as part of our research.
> - If we want to understand how learning happens in complex situations, then we should study learning as it is occurring in those environments – with all the messiness of the real world and requiring methodologies that can nonetheless extract trends and descriptions.

- Design is an important kind of research in and of itself, not simply done in service to investigation.

Learning sciences is a design science, an integration science, a socio-cognitive science, a descriptive science, and an experimental science, all carried out in Pasteur's Quadrant (Stokes, 1997). Basic research in the learning sciences addresses real world needs but is basic nonetheless. The community includes immigrants and tourists from cognitive science, science education, educational technology, educational, developmental, and cognitive psychology, computer science (HCI, AI), information science, anthropology, and even a few from instructional systems design. We go to the ICLS, CSCL, EARLI, and AERA conferences, easily find each other at AERA sessions that we tend to gravitate to, belong to the same two AERA sigs, subscribe to, read, and prepare manuscripts for JLS, and have created and joined the International Society of the Learning Sciences (ISLS; www.isls.org). Those of us who are immigrants continue to write for, participate in, and attend the conferences of the cognitive science, science education, and other communities we immigrated from.

Since 1989, we have evolved into a community of practice. We grapple together – in print and formally and informally at our conferences – about methodology issues and important philosophical questions. Over the past decade, we've added a generation of young researchers educated by immigrants to the learning sciences as first-generation learning scientists. Our first set of first-generation learning scientists is educating the next generation, taking on major review responsibilities for *JLS* and major conference and society leadership positions. They began coming up for tenure in education schools and computer science departments over the past few years, and in the past year, we've seen a significant increase in schools that are specifically seeking learning scientists for their faculties. Indiana University, Vanderbilt, Wisconsin, Stanford, and perhaps others, have joined Northwestern in having official learning sciences graduate programs. Other universities are exploring the creation of such programs or creating graduate programs that have learning sciences as one of their centerpieces. One of our challenges will be to continue to enrich the research community the Learning Sciences evolved from even as we strengthen our newly created community of practice.

End of learning sciences story for now.

3 Learning Sciences (LS) v. Instructional System Design (ISD)

Where does that leave us with respect to comparing the learning sciences and instructional system design? I think the most important thing to notice in my history of the learning sciences is that until my next to last paragraph, I didn't mention ISD. That field simply didn't figure in the development of the learning sciences. Some of its practitioners have participated (e.g., David Jonassen), but in general, there has not been an active relationship, nor has there been, until recently, a move toward creating a relationship. Why not? For many of the reasons put forth by Barab (this issue), Duffy (this issue), Hoadley (this issue), and Smith (this issue), I think. Let me add my two cents on each.

1. Learning sciences focuses on promoting learning in new and creative ways. We'd love to have what we're doing integrated into schools and other learning environments, but our

research is generally aimed towards what will be possible in the future. I gather that ISD, by comparison, has tended to focus on designing ways of promoting learning in environments that are pretty close to what's current. As schools think a bit more constructivist, so does ISD, requiring, perhaps some new design principles. And as learning scientists think more socially constructivist, ISD research might evolve in that direction. But ISD practitioners aren't generally aimed toward breaking new ground in this area. Learning sciences is revolutionary; ISD seems evolutionary from what I know.

2. Learning sciences focuses on big ideas about learning and their applications, that is, on theory formation and exploration. Design is an important part of the research done in learning sciences, as it is for ISD, but generally as a means toward something bigger. For learning scientists, design of systems and the environments in which they are used, and analysis of what happens in those environments, provide a means for developing and investigating big ideas. Design principles derived from those designs and aimed at helping us design better for deep and lasting learning is an important kind of big idea. Big idea papers tend to present enough of the designs of systems and learning environments to be able to make claims about learning, but, truthfully, we've found it particularly difficult to help authors craft papers about design principles for *JLS*. Because we want everything we publish to be grounded in theory, papers that draw design principles from software designs have big requirements on them. For example, the designs the principles are drawn from need to be founded in modern learning sciences literature, and analysis of their efficacy needs to focus not only on student learning but also on the ways they are used and the roles the software and others in the environment play that contribute to success. This is an area where I think LS and ISD researchers should try to make progress together, but we certainly haven't shared goals in this area up to now. I say more about this below.
3. Learning sciences is an offshoot of cognitive science. Like cognitive science, it seeks to explain learning. ISD simply hasn't been focused on that goal.

While learning sciences is more scruffy and ISD more neat, learning sciences more socially constructivist and ISD more individually constructivist, I don't think either of those differences is what accounts for learning sciences and ISD not having met up until recently. Rather, those things emerge from learning science's long-term focus on big ideas and theory building vs. ISD's pragmatic focus on design methodology.

So I largely agree with all of the authors about the differences between LS and ISD. It's hard, however, from my perspective, to agree with Chris Hoadley and Brian Smith that LS and ISD should have been paying more attention to each other all these years. Learning Sciences needed the past 15 years to grow and mature as a field and become a community of practice. It's important for researchers to understand their foundations, strengths, weaknesses, and assumptions before branching out. Research collaborations that begin with researchers who understand those things about their fields have the potential to make more deep contributions together. Learning sciences needed the past 15 years to develop, and it would have been confusing to add another worldview before we knew who and what we were.

4 A possible future together?

That being said, I agree wholeheartedly with all of the authors that the time has come for the two communities to work together, and I think there could be real benefit in having some of each community join forces for several focused projects. Learning scientists need some particular help right now – help that ISD researchers and practitioners might be able to provide. Tom Duffy laments that LS researchers haven't been putting enough effort into further developing our conceptual and theoretical base. I agree. We need to begin putting more effort into that endeavor. We believe that our investigations in the real world should lead to both good designs and learning about learning, but too many of us focus on the design side and neglect the learning part (doing design studies rather than design experiments). I think it's because so many of us have been asked to engage in development efforts. Most of us began as researchers, designing software and curriculum materials for the future, and using them to understand learning, but many of us have found that if we want to have impact on education, we need to be intimately involved in turning our designs into products. But we do want to have impact, and NSF and other funding agencies are pushing us to move in that direction.

But there simply aren't enough hours in the day for us to work both on developing what we're doing into products and using our designs in progress to help us learn more about learning. And learning and education research don't have the kind of infrastructure (like medical and bio-medical research has) that allows researchers to pass their research on to others (designers) who can do the research and development needed to make them into products. Added to that, most learning scientists are ill equipped for (and not all that excited about) evolving our research prototypes into curriculum units and software designs that can be used by broad numbers of teachers and students. Yet if we publish and distribute our software and curricula as designed (and some of us are working towards that), we know they will reach only a very small number of learners in very progressive school systems or with risk-taking and creative teachers (the ones who are probably doing just fine teaching without our materials).

Nor do I think that learning scientists should be turning our materials over to ISD researchers and practitioners and asking them to evolve them so that they are closer to traditional materials. I don't think such refinement will work without learning scientists involved. But I do think there's an opportunity right now for us to create a new field of practice from our two fields. It will require learning scientists and instructional system designers working together to imagine how to refine our materials in ways that allow the really important parts to stay and allow those broadly-usable designs to evolve over time into designs more in tune with our intentions. It is possible that through the complementary strengths of learning scientists and instructional designers, we can create an infrastructure for moving "boutique" ideas and designs from learning sciences research into more broadly disseminatible products.

It would be hard work for researchers on both sides, and I don't think we should all make such an endeavor our business. But what I foresee is that some learning scientists who are particularly interested in bringing the best of research into classrooms (and informal settings) will work with some instructional designers who are particularly interested in using what we know about learning to design for classrooms (and informal settings). Learning scientists would bring their expertise on learning theories, educational approaches, collaborative learning, nifty technology, and learner-centered design, and their imaginations about the roles software can play in learning. Instructional designers would bring their expertise on classrooms, design methodologies, and

evolutionary design. Teams would include a range of learning scientists and instructional designers who span the range of expertise and capabilities needed for a particular project. Each team member would also commit to learning more about the areas of expertise of the others. Instructional designers would have to commit to getting to depth in their understandings of learning theories and educational approaches, and learning scientists would have to learn how to let go of the whole dream and be willing to go for good enough. Together, such teams could negotiate refinements and pathways from research ideas to broadly usable and acceptable designs for teachers and administrators (and parents). The goal would be to design educational materials that are within the zones of proximal development of those who choose and use them and that scaffold those people to the next level; then to have the next set of materials ready to take those people the next steps; and so on. I see the possibility for really interesting work on teacher development and systemic reform coming from such efforts in addition to design principles and effective products.

Such a coalition would provide opportunities for its learning scientists to focus on what they do best – looking to the future – and its instructional designers to do what they do best – design practice for broad use, while providing opportunities for all involved to grow. Putting such an infrastructure in place would allow more of us in the learning sciences community to get back to our roots and focus on research that allows us to refine and strengthen learning sciences' conceptual foundations.

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