1 Introduction

Evolution of Research in the Learning Sciences

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Over the past 25 years, the interdisciplinary field of learning sciences has emerged as an important nexus of research on how people learn, what might be important for them to learn and why, how we might create contexts in which such learning can occur, and how we can determine what learning has occurred and for whom. At the same time this emergence has prompted repeated attempts to probe and elucidate how learning sciences is similar to, as well as differentiated from, long-established disciplinary research areas, such as anthropology, cognitive psychology, cognitive sciences, curriculum and instruction, educational psychology, and sociology. This is a difficult question to answer, in part because the learning sciences builds on the knowledge base of many of these disciplinary research areas while at the same time taking a "use oriented" perspective on the knowledge base. That is, much as Stokes (1997) distinguished between basic research and research oriented toward solving practical problems, (i.e., research in Pasteur's quadrant), research in the learning sciences is often situated in problems of practice that occur in a range of "learning" contexts, including formal or informal settings dedicated to schooling, workplace, or leisure/entertainment goals.

Because the learning sciences are "use oriented," they are also holistic; practically useful knowledge needs to be coherent (Bereiter, 2014). When we speak of the learning sciences as aiming for a holistic understanding of human learning, we take both epistemic and systems views. The epistemic perspective is that learning can be studied from multiple perspectives. By claiming that human learning is a systems phenomenon, we assume that learning is brought about by the coordination of biological learning with socio-cultural knowledge and tool production. Just imagine—and this means asking for the impossible—how different human learning would be if we would not have language to communicate, would not have writing systems, including those for mathematics and music, would not have invented technologies, from tables to tablets. None of these essential elements of (and for) human learning depend on a particular brain function; instead, each extends the brain—the biological system—into a bio-socio-cultural hybrid system that is the locus of human learning, and generally for human cognition (Clark, 2011).

In a similar vein, concerning methodology, the learning sciences have resisted crude reductionism. Instead, what is often practiced is a kind of dialectical reductionism, for lack of a better word. To produce good explanations for learning, the learning process(es) under study needs to be decomposed into parts, and the explanation runs 'upwards' from the components, and their configurations and coordinations, to the process that gets explained. At the same time, the lower level processes get meaning only when seen from the higher level: moving an arm up or down is part of a dance move or directing traffic cannot be determined from analyzing the motor control processes in the brain, as little as from analyzing the muscle contractions in the arm. Any human action, other than reflexes, can serve multiple—indeed, infinitely many—purposes. Furthermore, most of our actions are tool-mediated, which makes them mediated by the culture that provides the tool and the community of practice in which a specific way of using the tool makes sense (Wertsch, 1998). Although learners may neither be aware of the body and brain processes, nor of the cultural pedigree of their actions, to understand human learning, and to shape it, all of these need to be taken into account.

Purposes

The overarching purposes of this handbook are to bring together international perspectives on theoretical and empirical work (1) that has informed the research agenda of the learning sciences, with its emphasis on design and how learning technologies (computer and internet based and otherwise) can support learning and its assessment; (2) that comprise signature and unique contributions of learning sciences design research cycles to understanding how, what, why, and for whom learning is happening; and (3) that comprises the multiple and complementary methods of examining learning and how it happens within learning sciences research traditions. In so doing, we hoped to create an internationally oriented up-to-date resource for research and teaching in the learning sciences.

We intend the handbook to serve as a resource to the burgeoning number of post-baccalaureate programs in the learning sciences. In the past decade, the numbers of programs describing themselves as providing advanced degrees in learning sciences has gone from just a handful to more than 50 worldwide (see isls.naples.com). Many more programs in education, psychology, and related fields include specializations or subprograms in learning sciences. The programs are geographically distributed across North America, Europe, Asia, and Australia, with emerging interest from South America and Africa.

We also intend the handbook to provide a compendium of past, current, and future research trends. The contributors to this handbook are actively participating in learning sciences research and graduate preparation programs; have served as editors or editorial board members of the premier journals of the learning sciences, the *Journal of the Learning Sciences* and the *International Journal of Computer Supported Collaborative Learning*; or have played key roles in the activities of the International Society of the Learning Sciences, including the annual meetings. They are thus well positioned to both introduce newcomers to the learning sciences to its major theories, methods, and empirical findings, as well as to provide for more seasoned members of the learning sciences communities well-informed and reflective perspectives on major trends and future directions in their specific areas of expertise. In soliciting authors, we provided content guidelines that we hoped would provide some consistency across a diverse set of topical areas. We asked that the authors provide a brief historical introduction to the topic and discuss the relevance or intersection of their topic with the learning sciences. They were asked to refer to empirical studies and their findings to support claims and/or provide examples of the application of particular research methods or analytic strategies. We encouraged the authors to avoid the "not invented here" syndrome and seek out international scholars working on the specific topic.

Given the limited length of each chapter, we asked the authors to include four or five further readings with a brief annotation, along with the citations included in the body of the chapter. In addition, most of the chapters include a section with links (URLs) to specific video resources, most of them part of the NAPLeS (Network of Academic Programs in the Learning Sciences) collection of webinars, interviews, and short videos. We encourage you to take advantage of these additional resources.

As editors of the volume our purpose in the remainder of this introduction is to provide an overview of the three sections from the perspective of what we hoped to capture and reflect in each. We focus on overall trends across sets of chapters rather than providing summaries of each. We conclude with several emergent trends and directions for learning sciences, including greater attention to social responsibility and research that speaks to issues of equity.

Organization of the Handbook

Learning sciences is an interdisciplinary field that works to further scientific understanding of learning as well as engages in the design and implementation of learning innovations in methodologies and learning environments intended to improve learning processes and outcomes. Conceptions of learners, learning spaces and places, the time span over which learning occurs, what manner of processes and outcomes are defined as evidence of learning all reflect the interdisciplinarity of the learning sciences. The first section of the handbook, 'Historical Foundations and Theoretical Orientations of the Learning Sciences,' endeavors to reflect foundational contributions to this interdisciplinarity as well as the particular way in which the learning sciences has taken up these contributions and then used them to create its own brand of use-oriented theory, design, and evidence. The second section, 'Learning Environments: Designing, Researching, Evaluating,' turns to various configurations of places, spaces, time frames, tasks, processes, and outcomes that constitute the what of learning sciences research, design, and evaluation. The third section, 'Research, Assessment, and Analytic Methods,' reflects the methodological diversity of the learning sciences. We discuss each section in turn and conclude with the themes and trends that emerge for the future.

Section 1: Historical Foundations and Theoretical Orientations of the Learning Sciences

The history of science is replete with paradigm shifts stimulated by the accumulation of evidence that simply did not "fit" extant theoretical paradigms. Such was the case with the "cognitive revolution" in psychology during the 1960s (see Miller, 2003). Similarly, the learning sciences emerged in part as a response to evidence and phenomena of learning emanating from different disciplines. However, rather than a paradigm shift within a single discipline (e.g., psychology), the seemingly inconsistent evidence and phenomena were emanating from different disciplines, leading to a shift to a more *inter*disciplinary conception of learning. For example, the juxtaposition of sophisticated quantitative reasoning in everyday situations seemed at odds with data indicating that people were far less successful in such reasoning in formal school mathematics (Lave, 1998; Saxe, 1991). As Hoadley indicates in his "short history," four themes emerged as characteristic of the learning sciences and form the foundations of the epistemology as depicted in Chinn and Sandoval. The next set of three chapters (Danish & Gresalfi; Eberle; Reimann & Markauskaite) detail productive tensions of efforts to look at learning, development, and expertise from individual "in the head" as well as socio-cultural perspectives. Two chapters draw attention to the importance of looking at multiple systems in which learning occurs, in particular the neural system (S. Varma, Im, Schmied, Michel, & K. Varma) and the motor/kinesthetic system reflected visibly in action and gesture (Alibali & Nathan). This work points to productive future directions for work in the learning sciences in attempting to understand learning as a multi-level phenomenon.

A theme of the next four chapters reflects the increasing consideration in the learning sciences of the purposes and goals for which people interact with and try to make sense of the various forms of information that are ubiquitous in the 21st century. Why do people turn to certain information resources whether in everyday life, academic, or professional endeavors? This theme runs through the next four chapters—by Goldman and Brand-Gruwel; Ainsworth; Herrenkohl and Polman; and Renninger, Ren, and Kern—from different perspectives, ranging from general interest to disciplinary inquiry in formal and informal settings. They discuss the influence and interconnections between learners' perspectives on the purposes and functions of their efforts, how they define and how deeply they engage with information they decide is relevant to their purposes, and what they learn. Furthermore, epistemic goals and values emerge in interaction with others, as a collaborative and collective activity, whether in educational or workplace settings (Järvelä, Hadwin, Malmberg, & Miller; Cress & Kimmerle; Ludvigsen & Nerland). Learners do not operate in isolation from the people and objects in their worlds. They build shared understandings via processes that require regulation and modulation in interaction with others and as shaped by and shaping the contributions, knowledge, and beliefs of self and others. Section 1 concludes with a very apropos chapter on complex systems (Yoon), addressing the issue that many of the properties of complex systems (e.g., emergence, structure/function relationships, causality, scale, and self-organization) pose substantial teaching and learning challenges in K-12 education.

Section 2: Learning Environments: Designing, Researching, Evaluating

Much of the work in the learning sciences is concerned with designing learning situations that are challenging for learners, that ask them to grapple with situations, tasks, and problems for which they do not have rote solutions or for which they cannot simply call upon a memorized factoid. They are asked to work just beyond their comfort zones, in what Vygotsky (1978) referred to as the Zone of Proximal Development (ZPD). To be successful working in the ZPD, learners require supports. The second section contains chapters describing approaches to designing learning environments that support learners' engagement in ways that lead to knowledge and dispositional outcomes that prepare them to be able subsequently to use what they have learned in conditions different from those of the original learning. Learning activities typically have an inquiry or problem-solving orientation and more often than not involve both independent and collaborative work.

Learning environment designs reflect a variety of learning contexts, pedagogical approaches, and supports for learning. Contexts range across formal and informal educational institutions; informal, opt-in spaces and places (e.g., sports clubs, after school, affinity groups); home, work, and other institutional settings. Pedagogically, designs run the gamut from prescriptive to co-designed to learner-centered. Supports for learners, broadly referred to as scaffolds, may be built into tasks and task sequences provided to do the task, guidance or other forms of coaching and feedback. Scaffolding requires the presence of a "more knowledgeable other", a role that may be played by humans (e.g., peers, tutors, teachers, parents), computers, or a mix of the two. The chapters in this section attempt to reflect the diversity of designs that result from various combinations of contexts, pedagogies, and forms of support.

The first four chapters present relatively broad, big picture-perspectives on pedagogical designs (van Merriënboer & Kirschner; Dillenbourg, Prieto, & Olsen), scaffolding (Tabak & Kyza), and one specific genre of scaffolding, examples (van Gog & Rummel). These four chapters provide some general considerations for design across a variety of tasks and disciplinary contexts. The focus then shifts to particular forms of inquiry learning, raising considerations of the timing and specificity of guidance and feedback (Hmelo-Silver, Kapur, & Hamstra; Linn, Gerard, McElhaney, & Matuk). Both chapters imply important roles for technology. Indeed, the subsequent chapters in this section involve technologies for supporting learning in a variety of different contexts, disciplines, and learner configurations (individual, small group, whole class). Specifically, Lyons examines issues that arise in introducing technologies in different types of informal learning institutions and the importance of considering the institution as an ecosystem. Computers as intelligent tutoring systems (Graesser, Hu, & Sottilare) and vehicles for providing learners with experiential learning through simulations, games, and modeling (de Jong, Lazonder, Pedaste, & Zacharia) have been used to support learning in a variety of content areas, most frequently in the sciences and mathematics, sometimes focusing on individual learners and sometimes supporting multiple learners working together. The contexts and situations reflect design characteristics of inquiry and problem solving.

Design activities as a vehicle *for* learning are the focus of the next three chapters in this section. Recker and Sumner discuss how teachers' learning through their instructional design efforts is enabled and supported by resources available on the internet. Fields and Kafai review major findings from research on game-based learning, showing that designing games can be highly effective for learning, especially if learners engage in scaffolded design activities. Halverson and Peppler analyze the maker movement and identify two characteristics as core features: authenticity and purpose in making, and self-selection and agency in choosing a particular maker activity. These features of Makerspaces may make them particularly interesting sites for attending to equity and diversity in learning.

The next eight chapters discuss various ways in which collaboration and knowledge building have been major goals of design efforts in the learning sciences from its inception. Indeed, a seminal computer-based system to support collaboration around the development of ideas, CSILE (Computer Supported Intentional Learning Environment), arose out of Scardamalia and Bereiter's efforts to foster knowledge-transforming rather than knowledge-telling learning opportunities (Bereiter & Scardamalia, 1987a, 1987b; Chan & van Aalst). Since this seminal work and the profusion of design and research projects that it has spawned internationally, there have been a number of parallel design and research efforts that emphasize creating and generating knowledge in scaffolded communities of inquiry (Slotta, Quintana, & Moher) or through dialogic and dialectic argumentation (Schwarz). After a theoretical and methodological overview of these efforts in CSCL research (Jeong & Hartley), the following two chapters discuss approaches that have attended to more specific issues. The designs are typically realized in computer- or internet-based systems and provide various types of support for collaborative knowledge construction, including scripting and scaffolding for groups (Kollar, Wecker, & Fischer) or group awareness information supposed to help groups regulate their activity themselves (Bodemer, Janssen, & Schnaubert). The final two chapters of that section emphasize collaborative learning opportunities that are already at scale in K–12 as well as higher education: mobile learning (Looi and Wong) and massive open online courses (G. Fischer). In these two chapters, the authors discuss the potential for linking formal and informal learning but also emphasize the value and importance of bringing a learning sciences perspective to design issues in these spaces.

Section 3: Research, Assessment, and Analytic Methods

The learning sciences first distinguished itself from other approaches by combining participant observation with systematic design and refinement efforts. Research focused on designing based on extant theory but researching the design in action for purposes of determining how to improve the design in situ was a signature characteristic of design-based research (DBR). The reflective redesign was the main vehicle for developing and generating theoretical positions beyond those from which the design had originated. In the first chapter in this section, Puntambekar details this history as well as directions that DBR has moved. Early DBR research reflected the "heavy hand" of the researcher on the design: researchers created for teachers and students, and watched what happened as teachers and students implemented the designs, consulted them about their experiences and suggestions, and then did the redesign. Similar enactments of DBR have occurred in informal institutional contexts and in game design. Lessons learned from these efforts have increasingly led to design approaches that involve the implementers in the process from the beginning, including design-based implementation research (DBIR) (Fishman & Penuel), and participatory co-design (Gomez, Kyza, & Mancevice). The process is one of working and designing *with*, rather than designing *for*, those who are intended users/implementers of what is designed.

It seems obvious that designers need to know what the designs they are creating are intended to produce in terms of processes and outcomes. Two aspects of this statement may not be so obvious. First, the level of specificity in process and outcome that seems sufficient to begin with, quickly prove to be too global and vaguely specified to really help with critical design decisions (Ko et al., 2016). Second, there is a paucity of longitudinal and even cross-sectional research for much of the disciplinary knowledge that is the target of designs intended for use in formal schooling contexts. Thus, design-based research efforts go hand in hand with assessment approaches that ask what we want students to know and be able to do and how we will know if they are making adequate progress toward what we want them to know and be able to do at specific points in their development and schooling. Pellegrino's chapter speaks to the centrality of these issues in both the design of instruction and the assessment of what students are learning, and the next two chapters (Duncan & Rivet; Ufer & Neumann) indicate approaches to addressing them with a longitudinal, cumulative perspective on learning.

The chapters on mixed methods (Dingyloudi & Strijbos) and on multivocality (Lund & Suthers) indicate the value of exploring data sets (in whole or in part) from multiple perspectives using different methods in combination to rigorously and systematically develop sound evidentiary arguments for empirical and theoretical claims. The next three chapters concern analytic approaches to various forms of qualitative data often captured in video and audio traces of interactions (Koschmann; Green & Bridges; Derry, Minshew, Barber-Lester, & Duke). The final four chapters discuss quantitative methods for the analysis of interaction (Vogel & Weinberger) that can be harnessed in service of constructing descriptive as well as predictive and causal patterns in the data of learning and instruction (Rosé; Shaffer). The final chapter in the section is on statistics for the learning sciences and suggests analytic strategies responding to the multi-level nature of the phenomenon of learning (De Wever & Van Keer).

Themes and Trends for the Future

We conclude this introduction by highlighting six themes and trends for future emphases in the learning sciences.

1 Increasing recognition of learning as a complex systems phenomenon. Learning and learning mechanisms operate at different levels and as semi-independent self-organized systems. For example, behavioral evidence of learning in an individual may be emergent from mechanisms operating in self-organized cognitive, affective, and kinesthetic/motoric systems, each of which has a neural signature. Furthermore, the individual is part of a larger socio-historical cultural system, and as such influences and is influenced by that system. Even as learning is attributed at the individual level, it is an accomplishment and attributable to the community collective(s) of which the individual is a member. While at the present time we have neither the theoretical, empirical, or analytic tools to investigate connections across more than a few of these multi-leveled systems, statistical methods like multi-level analyses and latent growth models are moving in directions that are much more attuned to the complex and dynamic multi-level phenomena of learning in real-world contexts that are of interest to learning scientists. The learning sciences is thus increasingly well positioned to elucidate at least some of the connections and emergent properties across levels.

2 Increasing emphasis on more precise and longitudinal explication of what learners are expected to know and be able to do, and what indicators would provide evidence pertinent to the targeted competencies. Research on learning progressions in a variety of domains will figure prominently in identifying targeted competencies. The results will be a tighter connection between the design of learning environments and the assessment of the learning that the designs are intended to support and promote. Thus, rather than assessment being external to the learning environment, it is part and parcel of its design from the beginning. Assessment positioned in this way can foster critical reflective practices in individuals and in groups of learners and potentially contribute to greater agency and self-direction. DBR and DBIR are excellent vehicles for incorporating this perspective on assessment. As well, new approaches to analyzing process and product data (e.g., talk, gesture, actions, problem solutions, written work) to identify conceptually meaningful patterns will make important contributions to these efforts. In many cases these

approaches will increasingly rely on automated or semi-automated analyses that capitalize on computer-based technologies.

3 More adaptive technologies in support of learning. From its inception, the learning sciences has incorporated various technologies in support of individual and collaborative learning. Automated analyses of response patterns reflecting behavioral, cognitive, and affective processes during learning and problem-solving activities are becoming increasingly sophisticated; they can provide a basis for more adaptive feedback to individuals and groups of learners but also support the teachers in their monitoring and intervention of students' learning. The nature of such automated analyses may enable the strategic selection of scaffolds based on detected patterns, a "just in time" provision of critical but apparently absent information, or guidance (e.g., hints or prompts) for learners' reflection and strategic decision making about productive next steps. However, to realize these potentials we need to combine these algorithmic approaches with our knowledge of learning and teaching. Learning analytics may become a success story to the extent that these combinations will be achieved. We are convinced that the interdisciplinary collaborations in the learning sciences are optimal pre-conditions to master this challenge.

4 In regard to methodology, the learning sciences have been developing a distinct blend of evidence forms, combining ethnomethodological and ethnographical research methods with more quantitatively oriented approaches to dialog analysis and experimental research. Increasingly, the different approaches are used in conjunction, as part of "mixed methods" strategies in interdisciplinary research projects. Although the chapter authors differ widely in the approaches they suggest for generating scientific knowledge, there is a noticeable convergence towards a balanced combination of qualitative and quantitative methods. This blend includes case studies and the detailed analyses of dialog and artifacts, as well as experimental (and quasi-experimental) variation of instructional conditions and contexts of learning. As such, the learning sciences are well placed to overcome the often-claimed incompatibility of qualitative and quantitative methods that has dominated methodological debates in education research.

5 Researchers engaged in design-based research increasingly emphasize designing *with* rather than *for*, of acting *with* rather than acting *on*. Historically, design and improvement efforts in the learning sciences—and more broadly in educational research—in large measure have been developed externally to the context of implementation. Generally, there has been minimal consultation with—and input from—those charged with implementing the resulting designs (typically teachers) and those whose learning is supposed to be impacted by those designs (typically students). Although the DBR cycle is intended to address such concerns, initial designs (and in some cases subsequent iterations) only partially addressed the issue of designing *for* rather than *with*. Designing *for* rather than *with* more often than not results in surface-level enactments and lack of ownership or investment in the success or sustainability of the effort. The learning sciences has begun to address these issues through greater use of participatory design and consultation, student-initiated and student-directed designs, and research focused on understanding the learning processes of researchers/designers as well as of teachers and students. We see this trend toward participatory design increasing as evidence accrues of its benefits to sustainable change.

6 Increasing attention to issues of social justice and equity. Moving forward the learning sciences needs to thoughtfully consider issues of equity and power as they shape and are shaped by our designs. We need to consider whether and how particular disciplinary content, epistemic practices, and outcome measures reinforce existing inequities and power structures, benefiting some learners but not others (Booker, Vossoughi, & Hooper, 2014; Politics of Learning Writing Collective, 2017). We have often failed to adequately examine context in ways that call attention to how power is circulating in learning spaces, where learners are coming from, and where learners are going. To fully realize its potential impact on teachers, policy makers, communities, and learners, learning sciences scholarship needs to more directly consider "issues of power and privilege, because power is always already there, in our research contexts, in our

articles and books, in our conferences, and in our classrooms" (Esmonde & Booker, 2016, p. 168). By thoughtfully considering issues of equity and power, we open up space for the learning sciences to more productively contribute to conversations about whether and how our research perpetuates existing power structures and reifies educational inequities. Doing so entails understanding and designing democratically for multiple levels of context: "the immediate setting in which individuals participate; relationships across the multiple settings that people navigate; the broader cultural, political, economic, and, indeed, ideological belief systems and institutional configurations in which these micro-level settings exist" (Lee, 2012, p. 348). We hope that future editions of this handbook will include more voices of those who explicitly focus on issues of social justice, equity, and power as well as engaging authors of other chapters in conversations about who is and is not being served by learning sciences research.

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Section 1

Historical Foundations and Theoretical Orientations of the Learning Sciences

2
A Short History of the Learning Sciences

Christopher Hoadley

The learning sciences is a field that studies how people learn and how to support learning. It is a relatively young scholarly community whose history reflects the influence of the many other disciplines that are concerned with learning and how to support it (e.g., anthropology, education, psychology, philosophy). Disciplinary communities reflect not just epistemological, intellectual, and methodological commitments in the abstract. Rather, as is well documented in the sociology of science, research fields reflect the people in them and both their interconnections and disconnections from other communities. Understanding these as well as their origins is enlightening with respect to what aspects of a field are core commitments, what aspects are hidden assumptions, and what aspects might merely be accidents of history. For these reasons, this introduction to the history of the learning sciences will be primarily about a community of people who dub themselves "learning scientists." And, like most historical accounts, this history reflects the perspective of the author. As a U.S.-based academician in the field for approximately 30 years, my familiarity is greatest with the North American parts of this story, and is almost entirely limited to the portions that were accessible through English-language research literature. As such, this chapter is best understood as "a" history, not "the" history.

My perspective is that the learning sciences are empirical, interdisciplinary, contextualized, and action-oriented. Throughout this narrative, I hope to illustrate the forms and functions through which the field of learning sciences manifests these four characteristics. Like most historical unfoldings, the path is twisted not straight. I will try to highlight how and when elements of these four characteristics start to emerge.

Seeds of Learning Sciences

Explorations of how best to teach are centuries old, but the scientific study of the nature of the mind and how it learns has its origins in philosophy and medicine. Around the beginning of the 20th century, there were several developments that marked what one might call the emergence of modern-day empirical approaches to the study of learning. On one hand, drawing on medical models, psychology began to emerge as independent of philosophy with different motivations and methods. For example, the physician Wilhelm Wundt used the methods of experimental natural science to understand phenomena such as human perception of color and sound. Sigmund Freud began to address so-called "nervous disorders" by trying to understand the nature of the mind—his empirical investigations involved introspection, leading to the invention of Freudian psychoanalysis.

Ivan Pavlov, the Russian physiologist, investigated the nature of conditioning in shaping learning after discovering physiological responses that preceded physical stimuli (such as dogs salivating before food was actually present in anticipation of a meal). In the early 20th century the biologist Jean Piaget studied learning as a manifestation of development, likening the maturing of children to the ways a flower might bloom, with biologically constrained possibilities emerging from the intersection of nature and nurture. Maria Montessori, trained as a physician, investigated children with disabilities near the turn of the 20th century and children's responses to various stimuli led her to begin creating the techniques used to the present day in Montessori schools. On the other hand, one countervailing force to these physiologically based approaches was a more contextualized way of conducting empirical research that emerged from philosophy, exemplified by the philosopher John Dewey. Dewey founded a laboratory school at the University of Chicago to study education within an authentic social context, one in which teachers and researchers were the same people. It is important to note that this was a time when many disciplines were working in parallel to formulate their core epistemologies and methods of approaching learning and education, including problems of explanation, prediction, and application to practical problems. The early to mid-20th century saw the empirical disciplines become more solidified and differentiated in academic institutions. For instance, not only did psychology become its own discipline, distinct from medicine, but psychology began to distinguish between experimental and clinical psychology. This posed an interesting question for how education would be institutionalized.

Generally, the shift from education as an applied profession to a legitimate area for empirical research was a contested one. In the United States, education in the form of teacher preparation was taught in 'normal schools' through the end of the 19th century, but this gradually was displaced by the notion of a school of education as a center for, not only practical training of teachers, but academic research relevant to the problems of education. By the mid- to late 20th century, most universities in the US had a school or college of education with a dual mission of preparing teachers and conducting educational research. However, Lagemann (2000) chronicles the history of educational research as contested terrain—at every level, especially methodology and epistemology. These tensions linked strongly to the characteristics of discipline, empiricism, contextualization, and action-orientation. From a disciplinary perspective, disputes focused on whether education was an intellectual (scientific) discipline unto itself, an application area to be colonized by 'real' disciplines, or a crossroads in which interdisciplinary inquiry could flourish. From an epistemological perspective, Dewey saw "an intimate and necessary relation between the processes of actual experience and education" (Dewey, 1938/1997, p. 20), and advocated for a holistic, pragmatic approach to the science of learning, while behaviorists like Tolman and Skinner saw human experiences as epiphenomenal and an invitation to pseudo-science. Skinner argued for the importance of the human environment as a source of conditioning for the individual, but saw the processes underlying learning as entirely universal, while Dewey saw learning as an inherently social, cultural, and societally embedded phenomenon. Methodological rifts were consistent with the epistemological: In the name of objectivity, the behaviorists advocated an arms-length, objective science of learning while the pragmatists and progressive education researchers took the positions of participant-observers in research. According to Lagemann (2000), behaviorism claimed the highest status among these epistemologies, but behaviorist theories increasingly ran up against phenomena that required hypothesizing hidden internal stimuli and other workarounds to keep the mind's "black box" closed while explaining human behavior. Openings to cognitivism also came from developmental psychologists' (most notably Piaget [1970] and Bruner [1966]), proposals that thoughts in the head mattered and that the stages of human development were less fixed than previously thought (see Olson, 2007).

By the 1970s and 1980s, and relevant to the challenge of "opening the black box" of the mind, two trends dramatically changed the landscape for people studying thinking (and by extension, learning): the advent of computing and the emergence of cognitive science. Beginning in the 1930s and 1940s, technology advances had led to both the field of cybernetics (studying the nature of dynamic systems that had self-regulating properties) and the use of metaphors like the telephone switchboard for thought and thinking. The emergence of digital computing birthed computer science, a field concerned with not only calculation of numbers but symbol manipulation more generally. Early on, the subfield of artificial intelligence emerged to design and study ways in which artificial symbol manipulation systems (electronics, digital computers, and software) could mimic intelligent behaviors exhibited by natural organisms like people. This approach included not only emulation of intelligent behavior, but using the computer as a model of the mind (Block, 1990).

In parallel, by the 1950s, debates about whether mental events and representations were empirically measurable had begun to chip away at Skinner's conception of thoughts as epiphenomenal, most notably by linguists like Noam Chomsky, who argued that language development was demonstrably not explainable with behaviorist theories (Gardner, 1985). Chomsky argued that mental machinery innately constrained language development beyond mere conditioning. Between the 1950s and 1970s, interdisciplinary examinations of thought started to reveal that not only the contents, but the mechanisms or machinery of thinking could be studied. Researchers began to overcome the limitations of introspection as the sole method of studying internal mental processes by drawing on techniques from a range of fields. For instance, Chomsky's argument was bolstered by much earlier medical research showing that damage to specific areas of the brain yielded very particular disabilities in producing or comprehending language. Reaction time studies and the methods of experimental psychology were used to attempt to infer the internal processes of thinking, from perception to attention to memory. The combination of computational perspectives focused on how to simulate or model thinking with artificial computational systems, and cognitive perspectives that viewed the contents and processes of thought as inspectable (breaking open the 'black box' with which behaviorists viewed thinking) created the conditions under which an interdisciplinary and empirical field calling itself cognitive science emerged (Gardner, 1985).

The degree to which cognitive science viewed thought as linked to the context "outside the head" increased over time; a special issue published in the journal *Cognitive Science* (Cognitive Science Society, 1993) posed a debate on how (much) cognition was "situated," i.e., inextricable from both physical and sociocultural context. On the one hand, you had the information processing psychology view which opened up cognition to inspection compared to behaviorism, but still treated the outside world as 'inputs.' On the other hand, you had the situated view, which helped establish a contextualized science for learning, in which learning at the minimum required investigating the social and cultural contexts of learning, and at the maximum treated learning as inherently a phenomenon not in the head but in the relationships between person and their context. Thus, prior to the beginning of the learning sciences, the cognitive science revolution helped establish more interdisciplinary approaches to thinking (and learning), with two effects: It laid the groundwork for empirical studies of learning to grow beyond black-box models, and it paved the way for examining learning as a product of context.

Early Learning Sciences (1980s–1990s)

The dilemma of how to leverage the interdisciplinary, empirical methods of the cognitive sciences for designing learning environments (action-orientation) while dealing with the messiness of learning-in-context, arguably led to the birth of what we now call learning sciences. The early history of the learning sciences was a time when the action-orientation and contextualization characteristics of educational research in cognitive science were being worked out. In 1989, I was at MIT pursuing what now might be called a learning sciences agenda while obtaining a cognitive science degree. I was working for Seymour Papert's Learning and Epistemology group at the MIT Media Lab, and simultaneously with developmental psychologist Susan Carey's research group studying conceptual change and scientific reasoning. I vividly recall a week in which colleagues in both quarters questioned why I was bothering with the other. The mantra at the Media Lab, "demo or die," contrasted with the traditional "publish or perish" in the psychology program. This question of which was more important—innovation and creative design versus scientific explanation and prediction—paralleled the difference between engineering and science. The tension I felt was more about how separating these two endeavors impoverished each.

Near the time of the arrival of more situated theories of thinking and learning, education researchers working in cognitive science grew somewhat frustrated with the degree to which cognitive science was distancing itself from cognition 'in the wild' (to borrow a term from Hutchins, 1995). The late 1980s and early 1990s can be marked as the birth of the term 'learning sciences,' and the field as such. Janet Kolodner, the computer scientist who founded the *Journal of the Learning Sciences* in 1991 clearly displayed an action-oriented stand in describing some of the motivations for the journal and the field. These included "need[ing] concrete guidelines about what kinds of educational environments are effective in what kinds of situations" and the need to make use of such guidelines "to develop more innovative ways to use computers" (Kolodner, 1991). In a retrospective history, she described how the cognitive scientists working at the Institute for the Learning Sciences founded in 1990 at Northwestern University were fundamentally as interdisciplinary as the cognitive sciences, but with additional linkages to educational psychology and curriculum and instruction (Kolodner, 2004). She also noted a frustration in the community with the lack of connection between what theories of cognition could predict (for example, with AI production systems) and what might be educationally relevant in real contexts. Kolodner highlighted that the action-oriented design mandate of learning sciences might contrast it with much of the cognitive science community in the 1990s for whom the design of artificial intelligence systems was primarily in service of generating theories and models of thinking. In that same issue of *Educational Technology* in which the Kolodner piece appeared, Smith (2004), a graduate of the first cohort of the Northwestern Learning Sciences Ph.D. program, drew a distinction between 'neat' as in lab-based and 'scruffy' as in field-based studies of learning. His characterization of learning sciences as 'scruffy' highlights the contextualized nature of the learning sciences' action orientation, and distinguishes the design research conducted by learning scientists from that done in the instructional systems design field. As well, each article described some of the milestones of the era leading to the creation of a community.

It was in 1991 as well that the first International Conference of the Learning Sciences was spearheaded by Northwestern's Director of the Institute for Learning Sciences, Roger Schank. Essentially, Schank renamed and refocused what was supposed to have been an Artificial Intelligence in Education conference. This renaming sparked interest in learning sciences particularly in the US, but had long-term consequences that made it more difficult to establish an international society of the learning sciences. During this same period of time, a community was coalescing around interests in computer support for collaborative learning (CSCL) with commitments to interdisciplinarity, and an action-oriented, empirical, and contextualized view of learning (Stahl, Koschmann, & Suthers, 2014). Following a workshop in 1989 in Maratea, Italy, in 1991, a workshop on CSCL was held in Carbondale, Illinois, hosted by Tim Koschmann, underwritten by John Seely Brown and sponsored by Xerox Parc. The workshop yielded a 1992 special issue of the newsletter of the Association for Computing Machinery (ACM) Special Interest Group on Computer Uses in Education. In 1995, the first biennial conference on Computer-Supported Collaborative Learning was held in Bloomington, Indiana, under the auspices of the ACM and the AACE (Association for the Advancement of Computers in Education) with an explicit attempt to alternate years with the ACM Computer-Supported Cooperative Work (CSCW) conference. Victor Kaptelinin from Umeå in Sweden gave a keynote on cultural-historical activity theory, and Marlene Scardamalia discussed knowledge-building communities, cementing the connection between the CSCL conference and sociocultural theories of learning and technology use.

Coincident with this five-year period of emerging conferences in CSCL and ICLS, there was an explosion of technologies that invited not only interdisciplinarity between technologists and educators, but also an action-orientation towards creating technology-mediated learning environments.

In the early 1990s, the web emerged (with the popularity of the Mosaic browser), as did the capacity to include video in consumer-grade computers (with the creation of Apple's QuickTime). Teleconferencing technologies were just barely getting out of the lab (for example, the CU-SeeMe software from Cornell). The emergence of commercial internet service providers at this time ensured that networked technologies, critical to collaboration, were widespread, and interest in educational applications grew beyond high-end training, government, and higher education settings to include learners at home, in grade school, and the general citizenry. Many members of the ICLS and CSCL program committees had appointments in computer science or informatics departments, a sharp distinction between these two conferences and most education conferences (even those with a focus on educational technology).

Several institutions played a role in bringing technology, design, and a contextualized view of learning together. The Institute for Research on Learning (IRL), began with initial funding from the Xerox Palo Alto Research Center (PARC). The IRL, directed by Jim Greeno, took culture and anthropology as seriously as technology and design. Similarly, the Lab for Comparative Human Cognition led by Michael Cole advocated a socially construed perspective on both learning research and learning design, and was an early adopter of technologies as a means to bring an action-orientation to social context (Cole, 1999). Many of the institutions which became known for learning sciences in the 1990s were places where interdisciplinary groups of faculty examined new methods for studying and designing learning settings, including notably Stanford and Berkeley on the West Coast, the Cognition and Technology Group at Vanderbilt, and so on. Each, of course, was different but in many cases these groups were supported by funding from the U.S. National Science Foundation or the McDonnell Foundation in projects that shared the four characteristics I've described of an interdisciplinary, empirical, contextualized, and action-oriented approach to understanding learning. The McDonnell Foundation alone, through its Cognitive Studies in Education Program (CSEP) funded approximately 50 such projects located in the US, Canada, or Europe over a 10-year period (1987–1997). CSEP was also foundational in building a learning sciences community through its annual meetings of grantees. In those early days of the learning sciences in the US, most of the theoretical stances were either cognitive or somewhat situative (rather than socio-political, cultural-historical, etc.). But interesting interventions implemented in the field were twinned with interesting learning theories that were design-relevant, including Brown and Campione's fostering communities of learning, Bransford's anchored instruction (Cognition and Technology Group at Vanderbilt, 1990), Brown, Collins, and Duguid's (1989) cognitive apprenticeship, Papert's constructionist environments for learning (Harel & Papert, 1991), Scardamalia and Bereiter's (1994) knowledge-building communities, Anderson's cognitive tutors (e.g., Andreson, Conrad, & Corbett, 1989), and Lave and Wenger's (1991) communities of practice. In each case, important claims about learning were asserted and tested by creating new genres of (mostly technology-mediated) learning environments. The particular mix of disciplines, theories, and approaches to action and context were different in other regions; for instance, Scandinavian researchers often drew on cultural-historical activity theory and participatory design approaches in this era. But one can argue that, in Europe as well as North America, there was a confluence of researchers representing these four characteristics, and that this challenged to varying degrees the particular entrenchments of "mainstream" educational research (for example, attempts to make education research generally more like the discipline of educational psychology).

Institutionalization of Learning Sciences (1990s–2000s)

By the late 1990s, both the ICLS conference and CSCL conference had established themselves. CSCL cemented itself as a field in two volumes edited by Tim Koschmann (Koschmann, 1996; Koschmann, Hall, & Miyake, 2002) and the *Journal of the Learning Sciences* was achieving outsized impact given its youth. Key contributions came in: cognition and learning (including elaboration of how conceptual change could be supported with technology scaffolding, both cognitively and interpersonally, the role of self-explanation, mental causal models, convergent conceptual change, and new theories of transfer); new methodologies such as interaction analysis, microgenetic analysis, and design experiments; and new approaches to technology including microworlds, tools for fostering communities of learners, tools for scaffolded inquiry, new models of intelligent tutoring systems and goal-based scenarios. Theories of situated activity, co-construction of knowledge, and distributed intelligence helped connect learning to its contexts. In general, all of this research fit the profile of interdisciplinary, empirical, contextualized, and action-oriented. For example, the LeTUS project at Northwestern and the University of Michigan attempted to scale up ideas about using technology to support inquiry science in the large urban school districts of Detroit and Chicago.

It was around this time that the learning sciences as a moniker for an interdisciplinary field began to take hold, as evidenced by data from the Google Books Ngram viewer shown in Figure 2.1. Figure 2.1 shows the prevalence within the Google Books corpus of the literal capitalized phrase "Learning Sciences" for the period 1980–2008, the last year for which data are available. Within North America, many scholars began to attend ICLS and CSCL in alternating years. At the time, ICLS had been held solely in the US, while CSCL had been held in the US and Canada. Both conferences were to some extent international, with attendees from Europe and, to a lesser extent, Asia and Australia (Hoadley, 2005). Although the conferences were organized informally, with the hosting university taking on financial management, there were real questions about the sustainability of this approach, which led Janet Kolodner (then editor-in-chief of *JLS*), Tim Koschmann (still considered a founding father of CSCL) and me (a newly minted Ph.D. with the job title 'research cognitive and computer scientist') to begin organizing a formal professional society that could house these three activities, support continuity, increase visibility and legitimacy, and provide financial stability. We began discussing the idea at the business meetings of each of the conferences in 1999–2000, and elicited experts from North America, Europe, and Asia who could serve on an interim advisory board to guide the founding of a society in 2000–2001.

Early attempts by the advisory board to define and name the organization revealed important differences in how different groups defined "the field" and felt about the two conferences and the journal. While CSCL had a track record of attracting an international audience, and the first European CSCL conference (dubbed "ESCSCL") was held in Maastricht in the Netherlands in 2001, the ICLS had had less success at attracting an international audience. Within Europe, strong networks of researchers were institutionalizing through formal networks such as the Intermedia project in Norway, the DFG Priority Program Net-based knowledge communication in groups, and

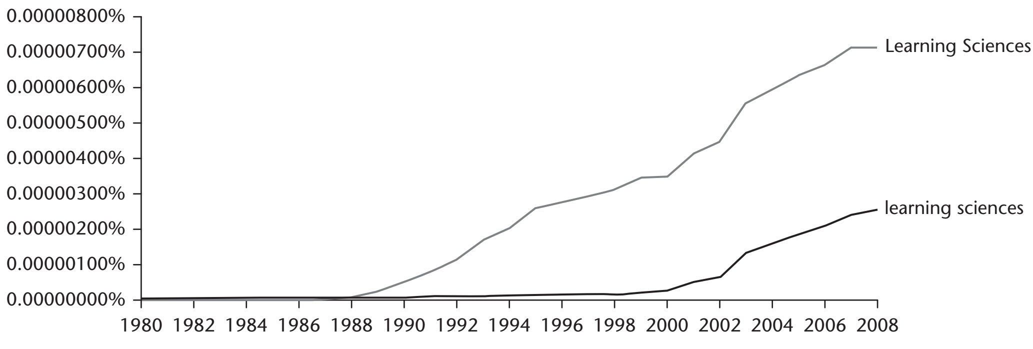

Figure 2.1 Prevalence of the Literal Phrases "Learning Sciences" and "learning sciences" in Works Indexed by Google Books, 1980–2008

Source: Google Ngram viewer. Retrieved July 27, 2017 from https://books.google.com/ngrams/interactive_chart?content=learning+sciences&case_insensitive=on&year_start=1980&year_end=2008&corpus=15&smoothing=3

the EU Kaleidoscope Network of Excellence on technology-mediated learning, which were formed in the early 2000s. In the US, a network called CILT (Center for Innovative Learning Technology) was funded by the U.S. National Science Foundation. These networks capitalized on many disciplinary networks in education research, including educational psychology and instructional design, but also helped incorporate technologists from computer sciences as well as human–computer interaction and informatics/information sciences. At the CSCL 2002 meeting in Boulder, Colorado, the interim board discussed the negative connotation that the name 'learning sciences' carried for some, given its connection to Roger Schank's unilateral renaming and co-opting of what was supposed to have been an AI in Ed conference. These connotations concerned many both in North America and Europe, although perhaps for different reasons. Indeed, many in Europe who were frequent CSCL conference participants had no affinity to either *JLS* or the ICLS conference. However, the interim board failed to identify a better alternative name for the society and the field it intended to support, and voted not to formally define the field, instead allowing the *JLS* and conferences to speak for themselves.

We continued our work and incorporated the organization in mid-2002 as the International Society of the Learning Sciences. Nine months later, during the ICLS 2002 meeting in Seattle, many participants were concerned that the Society should hold elections as soon as possible to allow wider participation in governance. We attempted to do so, and this backfired spectacularly. At the CSCL 2003 conference in Bergen, Norway, many Europeans saw the ISLS as an American takeover of a quintessentially European conference and scholarly community, a view exacerbated by the attempt to hold elections quickly. This led to a contentious business meeting and a negotiated agreement that CSCL would have a leadership committee within ISLS that was elected by the CSCL community, with some budget autonomy and a formal role in CSCL conference organization. Part of what had happened was that members of the community had been more insular than they realized. North Americans tended to go to both ICLS and CSCL but Europeans tended not to go to ICLS. They saw much of the work in CSCL emerging from European research, whether the traditions of participatory design in Scandinavia, with its strong tradition of research in cultural historical activity theory informing collaborative technologies, the experimental psychology research on collaborative learning processes in Germany, Belgium and the Netherlands, or some of the groundbreaking technology work coming from Europe in CSCW. Through an empirical analysis of the CSCL organizing committees and presenters, I was able to document that CSCL up to that point was truly an international, interdisciplinary conference, but that international collaboration was less strong than you might expect: the majority of CSCL papers were coauthored, but less than 10% of co-authorships were international collaborations (Hoadley, 2005).

In part to foster further internationalization and to avoid worsening any tensions between U.S. and European scholars, the next CSCL was held in Taipei, an important step towards truly internationalizing the society. Since then, both the ICLS and CSCL conferences have rotated among North America, Europe, and Asia or Australia. This has had a number of important outcomes over the years, including solidifying international exchange of scholarship (Kienle & Wessner, 2006). It appears from my perspective that the interdisciplinarity of the field has had a different texture in different parts of the world. For instance, in the United States, instructional design and learning sciences were different, whereas in the Netherlands, educational design and educational sciences were more connected. In the United States, it's quite common for schools of education to have departments of educational psychology, whereas in other areas of the world the psychology researchers might have less connection to schools of education and more to traditional psychology departments. Although the origins of the terminology 'learning sciences' may have been contentious, and there may still be debate about whether the field of CSCL is a subfield or a sibling of the field of learning sciences, the institutionalization of the professional society has been echoed in a shift in terminology in the published literature, in the naming of degree programs and institutes, and became a label for a stable and growing worldwide community of scholars.

Another important institutionalization of the field was reflected in the increase of visibility of design-based research methods as a core methodology for the learning sciences. Following on initial description of 'design experiments' by Collins (1992) and Brown (1992), in the mid-1990s a Design Experiment Consortium was founded, with many partners recognizable as members of the nascent learning sciences community. In the late 1990s, the Spencer Foundation funded the Design-Based Research Collective (Design-Based Research Collective, 2003) and a variety of other researchers began elaborating the method with special issues of the journals *Educational Researcher* (Jan/Feb issue, 2003), *Educational Psychologist* (2004, issue 4), *Educational Technology* (Jan/Feb issue, 2005) and the *Journal of the Learning Sciences* (2004, issue 1). This blending of design and research, while not universal in the learning sciences, nonetheless became identified with the community (Hoadley, 2004; Hung, Looi, & Hin, 2005) and helped entrench both the action-oriented and contextualized ways that the field conducts empirical research. As the principal investigator for the Design-Based Research Collective, I experienced firsthand how, while these methods often produced useful findings, they challenged core beliefs in the education community that followed from the tensions Lagemann had identified between the Deweyan and Thorndikean approach to studying learning. While now it is far less controversial to suggest that a designer of curriculum might be able to use their involvement in the creation and adjustment of interventions as they unfold in context to more effectively guide research, at that time it was seen as a gross violation of a notion of rigor that depended on a rigid separation between the 'objective' scientist and the educator or designer.

Finally, several books had an important impact on cementing the learning sciences. Initially published in 1999, the book *How People Learn* was written by a committee convened by the U.S. National Academy of Sciences, including a number of scholars active in the learning sciences community. This book helped consolidate in an authoritative way both the known findings about education and learning, and helped legitimize linking scientific research and practice (design) in education, advocating as one of its five core principles that we should "conduct research in teams that combine the expertise of researchers and the wisdom of practitioners" (National Research Council Committee on Learning Research and Educational Practice, Bransford, Pellegrino, & Donovan, 1999, p. 3). It also provided a framework that legitimized the role of context in both fostering and studying learning. Around the same time, Pierre Dillenbourg founded a CSCL book series at the publisher Kluwer (later absorbed into Springer). Two of the first volumes in the series were *What We Know About CSCL and Implementing It in Higher Education* (Strijbos, Kirschner, & Martens, 2004) and *Arguing to Learn* (Andriessen, Baker, & Suthers, 2003). And, in 2006, the first edition of the *Cambridge Handbook of the Learning Sciences* was published (Sawyer, 2006) (although, sadly, this edition contained almost exclusively U.S.-based authors). Thus, we see in this period a consolidation of the learning sciences as a field supporting interdisciplinary, empirical research that was both action-oriented and sensitive to the contextualized nature of learning. Although still in its infancy, methodologies, representative interventions, and core perspectives were emerging. To a large extent this period can be characterized as learning scientists finding each other and the common label for what they do.

Flowering of the Learning Sciences (2000s–present)

By the 2000s, the learning sciences, including CSCL, were flowering globally, with increasing institutionalization through the ISLS. Key achievements included the launch of the *International Journal of Computer Supported Collaborative Learning* at Springer and formal arrangements with the ACM's digital library to support archiving and indexing of society conference proceedings. The success of doctoral consortia associated with ICLS and CSCL conferences spawned the creation of conference-related workshops for early career faculty. As well, with the support of the ISLS, a Network of Academic Programs in the Learning Sciences (NAPLeS) was initiated. Both JLS and IJCSCL achieved impact factors that put them among the top five journals in educational research worldwide. Exchange programs started to crop up; for example, the US NSF (National Science Foundation) and the

German DFG (Deutsche Forschungsgemeinschaft) created a series of international workshops. The ISLS leadership began outreach efforts to articulate better with related societies such as the AI in Ed, Learning Analytics & Knowledge, and Educational Data Mining. After some drifting apart between learning sciences and computer science, funding agencies in several parts of the world were prioritizing work at the intersection of learning and computer science. These programs helped encourage new partnerships between computer scientists and education researchers at the forefront of both fields; in the US, this intersection was termed 'cyberlearning.'

Some of the key conceptual achievements of the field during this time included a deepening of the insights linking context and learning and further interdisciplinarity. For example, Gerry Stahl led efforts at Drexel University to examine cognition at the small group level through close study and design of software environments to support mathematics learning, leading to his theory of group cognition (Stahl, 2006). As well, an interdisciplinary, international team of psychologists, designers, and computer scientists released an important book on productive multivocality (Suthers, Lund, Rosé, Teplovs, & Law, 2013). Importantly, an edited book on critical and socio-cultural theories of learning brought new disciplinary perspectives on power and privilege to the Learning Sciences community (Esmonde & Booker, 2017).

The commitments in the Learning Sciences to action-orientation in conjunction with empirical research in context led to new developments in methodologies. Design-based research was augmented by design-based implementation research drawing on literature from improvement sciences (Bryk, Gomez, Grunow, & LeMahieu, 2015) and new models of research practice partnerships (Penuel, Allen, Farrell, & Coburn, 2015). The field also began examining new video-based technologies for studying learning (Goldman, Pea, Barron, & Derry, 2007; Derry, Minshew, Barber-Lester, & Duke, this volume), interfaces for detecting emotional states learners (Calvo & D'Mello, 2011), and big data approaches (Larusson & White, 2014; Rosé, this volume). Each of these techniques will undoubtedly be important in learning research generally, but each has come from individuals and groups with ties to the global learning sciences community and helps demonstrate the eclecticism, both in disciplines and in epistemology, that supports an empirical, contextualized, action-oriented interdisciplinary research community in the learning sciences. As I edit this, a new article has come out in *JLS* surveying the breadth of what self-described learning scientists do (Yoon & Hmelo-Silver, 2017). It demonstrates that the field is interdisciplinary with strong ties to both empirical research and design, using a broad variety of methodologies and mixed-method approaches, suggesting a sensitivity to contexts of learning.

Summing up: What Are the Learning Sciences Today and What Will They Be in the Future?

In an earlier paper, I described research communities as defined by scope and goals, theoretical commitments, epistemology and methods, and history (Hoadley, 2004). To these four, I would add a fifth today, coming directly from the word 'community': communion, i.e., being not only in communication, but also recognition and acceptance of each other's stances. When I was a junior scholar, *JLS* was one of the only places where eclectic methodologies were welcomed. At present, the Learning Sciences remain a community or field but not a discipline: People in the community retain allegiances to disciplines they call home, whether it is computer science, psychology, design, or any number of other disciplines. The Learning Sciences does not claim to have a monopoly on interdisciplinary approaches to studying education. Nevertheless, my claim is that, globally, learning scientists form a cohesive, yet diverse, community of scholars with enduring characteristics of interdisciplinarity, empiricism, attention to researching learning in context rather than in the lab, and action-orientation—the desire not only to study, but also to invent, environments for learning. Table 2.1 summarizes this evolutionary history to date.

Table 2.1 Evolution of Four Characteristics of the Learning Sciences Over Time (Empirical, Interdisciplinary, Contextualized, and Action-Oriented)

	Empirical	*Interdisciplinary*	*Contextualized*	*Action- or design-oriented*
Early 20th century	Empirical study of learning is emerging from medicine, biology, physics	Education moves from pre-disciplinary to becoming a discipline	Contested: Deweyan vs behaviorist approaches	Educational interventions just beginning to be connected to research
1950s–1980s	Experimental paradigm entrenched in educational psychology.	Psychology is established as a discipline. Education becomes a quasi-discipline, with major branches in curriculum and instruction, and educational psychology. Cognitive science begins bringing disciplines together	"Methods wars" show tension between quantitative and qualitative (contextualized) approaches in education schools. Most research attempts to explain culture within cognitive framing	Instructional design and curricular design well entrenched in U.S. schools of education but separated from development of learning theory
1990–2000s	Education moves towards randomized, controlled clinical trials as "gold standard." Other forms of empiricism are contested. In contrast, learning sciences embraces eclectic empiricism, including new methods	Education is entrenched as a discipline. Learning sciences explicitly draws on cognitive sciences and computer science	Situated cognition becomes a mainstay in learning sciences as well as in mainstream education Learning sciences links to older theories in cultural-historical activity theory and ecological psychology.	Learning sciences differentiates itself from education research writ large by linking design and research through novel methodologies (design-based research). Learning sciences considers applied research in schools even as cognitive science becomes less applied
2000s–present	Learning sciences continues to link to new forms of empiricism, including new ways of modeling through learning analytics and educational data mining	As a community, learning scientists become more established while residing in many disciplinary departments (computer science, education, communication, psychology, information science, etc.)	Learning sciences moves from primarily investigating individual cognition to a much greater emphasis on practices, groups, culture and language, and identity	Learning sciences' design orientation continues to embrace school settings and technologies, but also moves towards designing learning environments across contexts and through the lifespan. Design-based research and variants are taken up by other disciplines

Bibliometric analyses by Lund and colleagues indicate that education is one of the most cross-cutting intellectual areas within social sciences generally, outstripping fields such as psychology and anthropology (Lund, 2015; Lund, Jeong, Grauwin, & Jensen, 2015). Importantly, the analyses of Lund et al. (2015) indicate that many of the seminal publications related to the foundations and flowering of the learning sciences themselves are more likely to be cited across disciplines.

As I reflect back on the community, I am grateful. Intellectually, I came of age at a time when Learning Sciences was able to create an exciting space for action and reflection, science and design, innovation and insight. Some of the battles in creating this space were hard-won, including legitimizing the role of design knowledge as a valid product of scholarship (Edelson, 2002; Hoadley & Cox, 2009), insisting that we attempt to internationalize the community of researchers, and successfully navigating the tension between being a discipline versus an interdisciplinary field. The creation of a vibrant professional organization and maintaining the exceptional quality of two Society-affiliated journals has taxed a phalanx of the best scholars in the field. They have set aside their own work to edit, review, run conferences, and so on, usually without the built-in respect that would come from doing that work in the more discipline-based venues that align with the names of their academic departments. And, I keep coming back to this idea of communion—of being willing to recognize and embrace the epistemologies, methods, and theories of disciplines that are not one's own. As new students interested in learning encounter the community for the first time, they are often as excited as I was at the possibilities when we try to both understand and engineer learning with all the tools at our disposal. However, they also are frequently nervous about transgressing the norms of their home discipline. After 30 years of participating in this community, it is easy for me to tell them the results are worth it.

Further Readings

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Cognitive science is a major influence in the learning sciences. This is a good introduction to its history and hence to some important intellectual roots of learning scientists.

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Another discussion of how learning sciences overlaps with other fields, and some of the characteristics that define it.

Kolodner, J. L. (2004). The learning sciences: Past, present, and future. *Educational Technology, 44*(3), 37–42.

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Lagemann, E. C. (2000). *An elusive science: The troubling history of education research.* Chicago, IL: University of Chicago Press.

An excellent source for those who want to understand the philosophical, theoretical, and methodological tensions in educational research.

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This chapter focuses on the development of CSCL as a research field and community, both as part of the learning sciences and beyond.

NAPLeS Resources

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