
Title	Linking the learning sciences to teacher education: Teachers' beliefs, professional development, and scalability issues
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Source	<i>Educational Technology</i> , 46(3), 22-26
Published by	Educational Technology Publications

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This article was originally published in *Educational Technology*, Vol. 46 No. 3, pp. 22-26.
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Linking the Learning Sciences to Teacher Education: Teachers' Beliefs, Professional Development, and Scalability Issues

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Introduction

Since the advent of information technology some decades ago, there has been extensive research on how technology can be used in education. When the first author first started research work in designing intelligent tutoring systems more than twenty years ago, he joined a community seeking to explore the feasibility of building elaborate systems and

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demonstrating their functionalities. We would build systems and carry out controlled evaluations by bringing students to the lab to use a particular system. The goals were to show proof-of-concept, to build a prototype system, and to demonstrate its efficacy. Many educational technology systems were designed in this vein. Some of these systems were brought to the schools for further evaluations or for pilot studies. Such innovations, for the most part, were not sustained, for various diverse reasons.

Later, when the first author worked in an applied research institute, the motto was: the technology is only a part of the solution; it is not always the best technology that wins.

As we reflect on this, we would also say that pedagogy is only part of the solution; it is not always the best pedagogy that would be practiced in a classroom. A technology-enabled innovation with good pedagogy may be a run-away success, but that is not sufficient for its enactment in practice. Teachers may not want to use the technology, for reasons that may have nothing to do with the technology or the pedagogy. If there are champions of such technologies and pedagogies, there may be concerted use, but when the stakeholders change, the continued use is not sustained. Basically, systemic adoption depends on layers of sociological and political contextual reasons beyond that of technology use and better pedagogies.

Sabelli and Dede (2001) note that despite "decades of funded study that have resulted in many exciting programs and advances have not resulted in pervasive, accepted, sustainable, large-scale improvements in actual classroom practice, in a critical mass of effective models for educational improvement, or in supportive interplay among researchers, schools, families, employers, and communities."

Appropriately, many are investigating why the adoption of good ICT-enabled pedagogies has proven to be so difficult. How is it that global business is able to counter cultural and social differences and franchise its product, process, and even its culture successfully across the globe, while the adoption of good teaching practices in education seems sluggish in comparison? Although the reasons could be many and complex in nature, we believe that the key lies in the innovation not being sustained in schools for a period long enough to reap the desired teaching and learning results. Successful implementation must take into consideration the complexity of the educational system, societal needs, policies, curriculum, pedagogy, practices, epistemic beliefs, skills, and others.

Another critical reason for the lack of sustainability in the implementation of ICT-enabled pedagogies in schools is a failure to understand and foster the conditions for systemic innovations (Looi, Lim, Koh, & Hung, 2006). Researchers like Chris Dede and Barry Fishman have postulated how research work should be

conducted with a view toward sustainability (Dede, 2004; Fishman *et al.*, 2004), building up the capacity of researchers and teacher implementers to promote innovations (Linn, Davis & Bell, 2004), and developing new methods of analysis for studying sustainability (Dede & Wirth, 2006).

We argue that educating teachers with a Learning Sciences emphasis can enable them to serve as more effective change agents. We explore implications of recent work in the Learning Sciences community on how to build up capacity of researchers and teacher implementers with respect to their roles as change agents. As a teacher training institute, we (National Institute of Education) provide teacher learning and professional development. We also provide courses for school leaders and administrators. In such training, we have an opportunity to work with these school leaders to develop dispositions that foster reform-oriented uses of technology at the classroom level. In working at these different levels, and with preservice and inservice education workers, we have a chance to develop the human factor that affects the scalability, sustainability, and usability of innovations designed to support reform-oriented teaching and learning.

In this article, we emphasize that there is much that teacher education can gain from the field of the Learning Sciences. Learning Sciences is a relatively new inter- and multi-disciplinary field concerned with "how learning occurs." This key question can be understood from the sub-disciplines of neuroscience, cognitive science, educational psychology, linguistics, anthropology, computer science, biology, and possibly others. One central belief is that authentic learning occurs in the messy and complex situations of the real world, and hence is contextually situated. The methodologies ascribed by this field include Design-Based Research, and mixed quantitative and qualitative approaches to try and capture the richness of data that emerges in real situations. It adopts a developmental and historical-emerging perspective, where attempts are made not only to understand learning phenomena but to intervene with change strategies which are context-specific.

A Learning Sciences perspective is useful to enable teachers to see that learning is a complex phenomenon, and that a multi-disciplinary perspective to understanding learning does not fixate the mind on fixed instructional approaches as the context of teaching and learning changes. The Learning Sciences postulates an integrated view of learning that views learning as happening in different spheres and levels: at the informal learning level outside of school, at the formal level in the school, and at the individual level, in the neurological wirings happening in the mind. How do we translate such an expansive view of learning to teacher education?

Teacher education is concerned with how we

prepare teachers for schools—how teachers can teach and facilitate learning in relation to their professional practice. Increasingly, schools are moving in the direction of student autonomy in learning, and from recent teacher education literature, we recognize that they share similar orientations and issues with the Learning Sciences.

Congruent to the Learning Sciences perspective, the situated context plays a crucial role in learning. As such, the messy context and the multiple variables in any particular context make the learning and teaching situation unique. In this sense, studies conducted using Design-Based Research methods have limited generalizability. One realization in situated cognition research is not to derive a set of quantifiable and transferable tenets at the minute descriptive level, but rather to developmentally work with teachers and students in refining the activities to the point of success. What has changed in the entire context involves persons, activities, roles, and social rules of the activity, including the changes in conceptual understandings and possibly the epistemological beliefs of the persons involved. Clearly, what is "transferable" are the persons involved and the expertise they acquire when they undergo the change process. Hence, we concentrate on teachers as change agents. We argue that Learning Sciences has much to offer to the existing problems in ICT adoptions, pedagogies, teachers' mindsets, and teacher education (as a change process).

Changing Teachers' Beliefs

We start with our beliefs about learning—that learning should be about meaning-making, in which learning technologies can play a critical role. We assume that teachers' beliefs about learning spring from their implicit convictions of what learning means to their students and how knowledge is learned, whether transmitted or constructed. Moreover, with such an understanding, teachers provide the structures, processes, and scaffolding for students to learn with technology. Depending on their personal epistemologies, they are likely to integrate technologies in different ways.

Teaching and learning innovations may not always involve technology, but they have the catalytic ability to trigger change such that "one innovation will reverberate through other aspects of pedagogic practice and will touch upon the wider realm of a teacher's daily work so that it too will be changed" (Breen, 1994, p. 104). The design of innovations should support and foster inquiry-based, sense-making, and problem-solving types of pedagogies.

How then can the process of change be initiated in schools where innovation is both a catalyst and a facilitator for deep learning? What roles do teachers play as change agents? How can teacher education facilitate the development of the right dispositions,

attitudes, and skills towards understanding and utilizing technologies? In this sense, there needs to be research in the field of the Learning Sciences to understand teachers' beliefs, ontologies and epistemologies of knowledge and learning, and how this affects students. The current links of research in the Learning Sciences to teacher education need more emphasis, and we see this to be an important growth area in applying research to practice.

Obviously, change is not easily implemented and sustained, since a typical response from a rational human being to change is resistance. One of the issues faced lies in the tension between the desire to scale effective practice, on the one hand, and issues of adaptation and customization on the other (Honey & McMillan-Culp, 2000). In other words, how hard do we "rock the boat"? To bring about change thus requires strong leadership and shrewd management. Such a daunting task may not seem palatable at the onset to many school and policy leaders. Increasingly, if the field of the Learning Sciences is to make headway in schools, not just remaining in labs and documented in journals, this aspect of leadership and change management is crucial in enacting learning for students in schools.

Summarizing thus far, Learning Sciences should delve more into the process of changing teacher beliefs, and how to enact change leadership in schools. These issues are central to scaling up innovations arising from Learning Sciences research into school systems.

Scalability and Professional Development

Blumenfeld and colleagues (Blumenfeld et al., 2000; Fishman, 2002; Fishman et al., 2004) state that three dimensions within school systems are the key aspects to ensure sustainability and scalability of systemic innovations. These are: school culture, capability of practitioners, and policy/management; the three dimensions underlie their conceptualization of the Usability Framework. Together, the three dimensions, when arranged in the form of three axes originating from a common point, form the three-dimensional space known as the *usability cube*. An innovation can hence be placed within the space for gap analysis. Such analysis helps researchers in understanding the opportunities and processes one needs to look into for sustained success in schools. Teacher education can help us build up the capability of practitioners, as well as school leaders and policy-makers, which in turn will shape the school culture.

How do we enhance teachers' capability to enact complex, inquiry-oriented curricula? Professional development (PD) is a key to successful implementation of systemic reform. As Kubitskey and Fishman (2005) note, we know relatively little about what teachers learn from professional development, and we know even less about the impact of PD on classroom

enactment or students' learning. Fishman has developed a design approach for PD (Fishman, Best, Marx, & Tal, 2001). He advocates "Practice-Based PD," which is linked as closely as possible to what teachers must do in their classrooms, that is, based around curriculum materials. It is proximal to classroom enactment, and draws from what we know about "How People Learn" (Bransford, Brown, & Cocking, 2000). Practice-based PD emphasizes community-building.

When teachers and school leaders develop mindsets and epistemological beliefs relevant to student-centered ways of meaningful learning, they can potentially become change agents and influence others. We recognize that the issue of changing teacher beliefs is difficult and that multiple strategies are needed, of which professional development is one central feature.

Strategies for Teacher Education

A Learning Sciences focus can shape teachers' perceptions and philosophy to learning. In the preservice teacher program in our institute, teachers are exposed to the latest in learning theories and approaches, including constructivist learning and knowledge-building pedagogy. However, when teachers start their teaching in schools, they are typically drawn into the existing regime of the school, which typically means that teachers have a heavy workload. Because of necessary exigencies in work and large class sizes, they must resort to teaching in what seem to be the most efficient ways. After a few years of teaching, some teachers lose their zest and see teaching as a routine activity. When teachers use technology, they tend to take a limited instructional-design view of the use of technology, looking for prescriptions and templates. There is an attempt to enact the practice, but because the teachers do not fully feel the underlying principles and beliefs that undergird such practice, they may just enact the practice as an activity to be followed, and fail to fully exploit the benefits of the practice.

We hope and expect that at least some of the teachers who are exposed to knowledge-building concepts and strategies would teach with a changed epistemic belief and perception in their classroom practice. In our experience, our most viable strategy seems to start with the teachers we train or work with: a small group of school leaders, heads of departments, and teachers who share such dispositions. Another effective strategy is to work with students in our Masters and PhD programs. Given sustained interactions with their supervisors, these students acquire the epistemological beliefs of their supervisors. Moreover, these students have to carry out studies as part of their research projects and as a result have authentic situations, where they implement the newer innovations, such as knowledge building, in the schools. The

wealth of tacit knowledge and experiences gained by implementing such pedagogies in the schools provides these students with deeper understanding in the Learning Sciences. They become change agents when they are in schools. They have very progressive beliefs on how learning takes place, and have genuinely adopted the change into their teaching-facilitating process. They are the innovators in the schools, willing to try new teaching techniques, willing to take risks, and being open to adopting quite different styles of teaching and learning in the classroom.

Learning Sciences recognizes the need to conduct research on learning, where it is happening in the schools. Researchers work closely with the teacher implementers of selected educational institutions, thereby increasing usage of an innovation due to the strong capacity building in those educational contexts. The Design-Based Research paradigm provides feedback loops to the teachers to help them adapt and improve the innovation. These innovations can result in a direct bearing on the schools' social-cultural environment, thereby garnering more support and commitment, either through increased involvement of the teacher-implementers or strong support from the school leaders, such that innovations can be sustained. This will also help overcome the disconnect between researchers and policy-makers that has received considerable attention (Glover, undated; Lomas 2000).

In tandem, with an effective professional development model in place, changes can slowly be made with regard to classroom practice as well as personal epistemology of researchers and practitioners. Learning Sciences researchers, on one hand, will need to heighten their awareness of the actual classroom conditions that practitioners face, their epistemic beliefs, pedagogic skills, the level of mastery of the teachers, and the impact of change on schools as a whole. On the other hand, the right beliefs and dispositions will need to be inculcated in our preservice and inservice teachers, heads of departments and school leaders, and graduate students, to have expansive mindsets towards students' learning. They need to recognize that while they stick to what works for several years in preparing students to do well in examinations, they also must develop the competencies and skills that students need to live in a very different world, best characterized as complex, ambivalent, and relativist. When these "change agents" go out to schools, or go out to inspire and train more teachers, we hope to see a profusion effect, albeit slow in building, that will see a significant percentage of them pursuing their ideals and dreams about educational innovation, setting up good practices and inspiring others.

We believe that research in the Learning Sciences should yield tangible models which teachers can handle and adopt. These models include pedagogical

approaches, curriculum models, assessment rubrics and portfolios, frameworks which depict "ways of disciplinary thinking," and other change strategies. All these models serve as point-at-able models of practice (Bielacycz & Collins, this issue), which teachers can adopt in order to experience powerful ways in which meaningful and rich learning experiences can occur. In other words, Learning Sciences research needs to deliver in terms of resources which teachers can use. Through professional development, we also hope to build up the capacity of school leaders and teachers to be competent with these powerful pedagogies. See Figure 1.

We recognize that for teachers to be enculturated with the key competencies necessary for the 21st century, research evidence is needed to justify why alternative approaches are necessary. Many of us in the Learning Sciences to date have faced challenges in translating our research in a large way into schools, and we hope that in Singapore, with the mandate of the Ministry of Education (Singapore) and the National Institute of Education (solely responsible for teacher education, in this nation), we would have a good chance of achieving this goal.

Conclusion

We recognize that the field of the Learning Sciences is maturing and is likely to have a concerted impact on schools where students spend much of their time. Teacher education plays a crucial role in this theory-to-practice cycle. Over the last few years, Design-Based Research as a methodology has been emphasized as a kind of research that addresses the messy context of actual learning situations. We would propose that in the next decade of this field, considerations of how learning can be translated into practices in teacher education should be examined.

Much of the teacher-education literature to date emphasizes relativist thinking, where knowledge and curriculum are seen as process and praxis. In other words, traditional conceptions of teacher education are gradually being replaced with more current notions of post-modern epistemologies congruent to the Learning Sciences. Much research remains on how we can suggest practical and implementable strategies where learning and teaching are perceived as process-oriented. Notions of learning communities and communities of practice are also common in the teacher-education literature.

The Learning Sciences community can formulate design processes which can help translate theories into practice. The traditional conceptions of teaching have many parallel design processes, such as Gagné's instructional events adopted to design for content-knowledge. A similar concreteness needs to be evident in this field of the Learning Sciences, so that teachers as

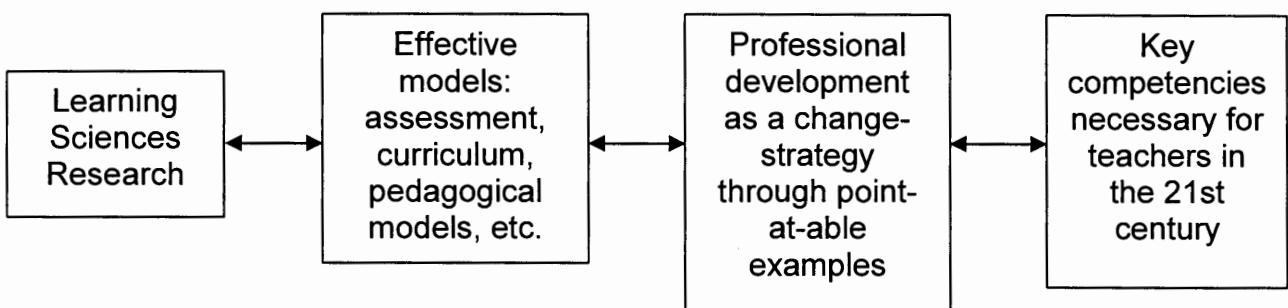


Figure 1. Linking Learning Sciences research to teacher education.

designers of learning can effectively design learning environments and activities, which are process- and collaboration-oriented. Such design processes are probably iterative in nature, such as through Design-Based Research methodologies where designers would design for constructivist learning environments and other forms of community-of-learners settings.

In this article, we have tried to establish linkages between the field of Learning Sciences and teacher education. We argue that a Learning Sciences emphasis, as compared with an instructional science focus, can help build and develop teachers' capacity in the educational workforce to be able to adopt IT-enabled innovations and to use them effectively. The challenge is to work with education workers at all levels so that they have the skills, capacity, and dispositions to use, adapt, and even construct innovations that impact student learning and are scalable and sustainable. If we want to increase the capacity of the field to engage in transformative work in the Learning Sciences, we must work with teachers and help them build such capacity. In this sense, the field of the Learning Sciences needs to make headway in teacher education and enact changes where leaders in education play a crucial role. □

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