Toward a New Learning Ecology: Professional Development for Teachers in 1:1 Learning Environments

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Abstract

As the nation's economy continues its irrevocable shift from manufacturing toward idea-driven, creative industries, our schools — and the teaching and learning enterprise at the heart of our schools — need to undergo a transformation as well. The result of such a transformation needs to be a type of educational experience and expertise that will not only support but also ignite participation in — and leadership for — an idea-driven, creative economy. Equally important as supporting a new economy is educational experience and expertise that supports a global citizenry. This paper argues for the importance of 1:1 laptop environments and related professional development initiatives as the catalysts for a new learning ecology that provide the dynamic educational reform described above.

Many colleges of education, specifically those emphasizing the preparation of teachers for proficiency with new literacies and emerging technologies, are uniquely positioned to play a pivotal role in the creation of the next generation of schools. Although the Department of Education's Race to the Top reform initiative (U.S. Department of Education, 2010) is highly competitive and also somewhat controversial, it points out the current administration's emphasis on innovation, especially with regard to 21st-century skills and tools.

This paper was written within the context of the NC 1:1 Learning Technology Initiative (2008), North Carolina's *Response to the Framework for Change* (North Carolina State Board of Education, 2008) and *E-Learning Commission Report* (2009), and the broader national and global demand for educational transformation. By "1:1 learning environment" we refer to a 1:1 ratio of mobile learning technology devices with Internet access to teachers and students. The laptop computer currently is the most prevalent but not the only device for achieving a 1:1 environment.

The ideas in this paper are set forth within the context of North Carolina's dynamic environment for educational change. In North Carolina, 1:1 teacher professional development systems are being designed in light of the State Board of Education's dual goals of producing students who are globally competitive and ensuring that all students are led by 21st-century professionals, goals consistent with the current push for innovative educational reform at the national level. The work of the 1:1 Learning Technology Initiative supports North Carolina's educational goals by emphasizing the need for every student to have ready access to a mobile technology learning device and the Internet (Corn & Osborne, 2009).

The work of The William & Ida Friday Institute for Education Innovation at North Carolina State University began with three foundational assumptions: (a) teachers are the single most important factor in determining student success, (b) professional development needs to be an integral, ongoing part of teachers' lives, and (c) our educational system must be transformed to support and ignite both an idea-driven economy and a global citizenry. Given this foundation, professional development was considered the key focus in producing teacher leaders who will not only continue to impact student achievement, but also help to transform classrooms and schools for the 21st century.

Considerable research has been conducted on professional development models, which in turn, has led to agreement on a number of key principles of successful practices for K-12 educators (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Sato & Darling-Hammond, 2008). These principles provide a broad design for conducting professional development for teachers but do not address directly the 1:1 learning context.

With this focus in mind, the specific purposes of this paper are to articulate the unique condition, that is, a new learning ecology, prompted by 1:1 environments, and to propose five key strategies that leverage the new learning ecology within 1:1 environments that can then be included in professional development systems for 1:1 teachers.

A New Learning Ecology Prompted by 1:1 Environments

The key feature that differentiates 1:1 instructional contexts is the simple fact that *all* students and teachers have access to a mobile learning technology device and the Internet. As a result of this initial access, students and teachers have ready access to vast amounts of information and tools for communication (e.g., instant messaging, email, desktop video conferencing, wikis, and blogs), productivity (e.g., word processing and spreadsheets) and creativity (e.g., for generating multimedia presentations, producing digital videos, and computer aided design), as well as the types of teaching and learning that these resources make possible. The word *access* is qualified, because simply having access to information and tools does not mean necessarily that the access will result in productive teaching and learning outcomes. Nevertheless, if each student has a mobile learning technology device and access to the Internet, the conditions for learning are fundamentally altered.

As Zucker and Light (2009) pointed out, computers are different than other technologies used in schools because they are "all-purpose machines" (p. 84). They can be used as a library, a museum, or a production studio to create knowledge artifacts in a variety of modes and media types, and they can also be combined with other technologies (e.g., cameras, probes, digital calculators, telescopes, and microscopes) to engage in focused educational endeavors. There is some evidence that allowing students to work with laptops can be effective in urban, under-privileged schools (Mouza, 2008). Given the effect computers have in the classroom, high quality and well-designed teacher professional development initiatives become even more crucial for 1:1 learning environments.

The constant access to tools and rich information in the 1:1 classroom can create what we refer to as a *new learning ecology*, in which information and ideas are abundant, in flux, and constantly evolving. Destabilization of information and knowledge is a critical factor within the contemporary learning environment, creating opportunities for new ways for students to be engaged and educated. John Seeley Brown (1999), who has written eloquently on the concept of knowledge ecologies, defined an ecology as "an open system, dynamic and interdependent, diverse, partially self-organizing, and adaptive" (p. 3). More recently, Barron (2006) defined a learning ecology as the "set of contexts found in physical or virtual spaces that provide opportunities for learning," which may include formal, informal, and nonformal settings (p. 195).

Building on these definitions, we offer a perspective for a new learning ecology that takes into account the unique contributions of a 1:1 setting—a learning-forward environment that takes on organic attributes with evolving interdependence among participants. We visualize a new learning ecology in which learning is multidirectional and multimodal. Learning, idea exchanges, and inquiry all take place within a dynamic system among students, teachers, and a global community. The system becomes open and dynamic as a direct result of 1:1 computing and access to the Internet.

Because the teacher is no longer the gatekeeper or proprietor of classroom information and knowledge, student dispositions and skills are challenged to evolve in order for students to take advantage of the human interdependence within the learning ecology. For example, in this environment interdependence among teachers and students is amplified due to the reliance on each other for critical information and perspectives. No one person possesses all of the skills and knowledge (technology knowledge, content knowledge, etc.) that are needed to function within the new ecology. The collective intelligence resulting from individuals and communities working with ideas and information needs to be leveraged (O'Reilly, 2006).

Not unlike the way flora and fauna rely on each other to grow and thrive within an ecosystem, students, teachers, and members of the larger global community rely on each other within the ecology to support learning and, most notably, processes and products of inquiry. As learners negotiate the inquiry process, they draw on the unique conditions of the learning ecology for support as they consider ideas and pose questions, analyze and synthesize information, evaluate and revise, and ultimately share, publish, and act on new knowledge.

In Figure 1, four unique, albeit tacit, conditions are illustrated that are prompted by the new learning ecology of the 1:1 environment:

- Immediate and constant access to information and a global community.
- Intensity, relevance and personalization of learning.

- Highly developed teacher capacities.
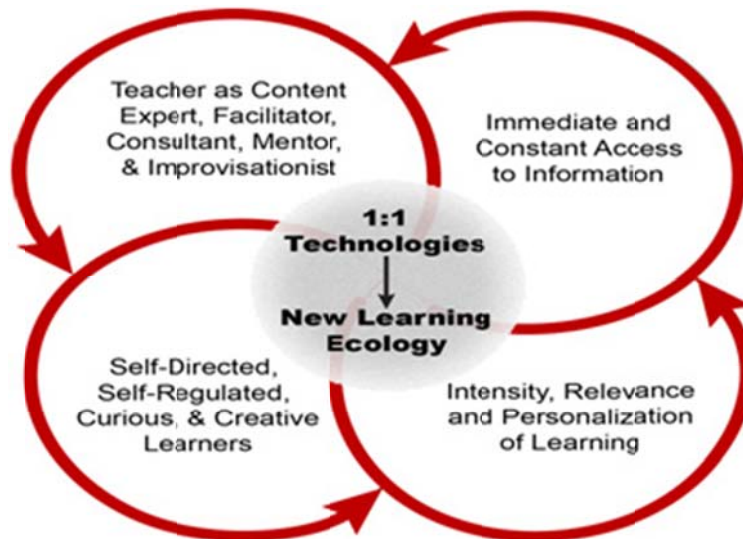- Highly developed student dispositions.

Figure 1. Four unique conditions prompted by the new learning ecology in the 1:1 classroom.

Immediate and Constant Access to Information and a Global Community

Twenty-first century standards and skills (e.g., innovation, creativity, problem solving, and collaboration) that are being promoted by the Partnership for 21st Century Skills (P21; 2004), the International Society for Technology in Education (ISTE, 2008), and many other organizations, including the North Carolina State Board of Education (2008; Dede, 2009a), are relevant and highly desirable for all teachers and students. The difference for teachers and students in 1:1 classrooms, however, is that they have the distinct advantage of immediate and constant access to information and a global community—and communication, productivity, and creativity tools. In a 1:1 environment, teachers do not have to wait to schedule the computer lab or have students take turns using a few computers in the classroom.

Obviously, the addition of technology ubiquity within the classroom does not in and of itself add value. Value is added depending on the ways the technology ubiquity is applied in the overall design for learning. For example, in a 1:1 mathematics class, students have constant access to technology tools for gathering and sharing information, visually and interactively exploring mathematical objects and relations, formulating conjectures, creating justifications or proofs, and presenting findings to peers.

Imagine the following scenario: The bell rings, students walk into the classroom, start up their computers, go to the course wiki to see what conjectures were posted by peers last evening related to an investigation about the medians of a triangle. Some of the conjectures posted include the following:

- The medians intersect in a single point.

- The point of intersection is always in the interior of the triangle.
- The medians divide the triangle into six smaller congruent triangles of equal area.
- The point of intersection divides a median in a ratio of 1:2.

Students begin placing their names next to particular conjectures on the wiki, form subgroups in class, move their desks and huddle with their teams to gather data using a dynamic geometry program to confirm or refute the selected conjecture. Some conjectures are easy to disconfirm by finding contradictory evidence; others seem to be true, but it is not clear why. Another is true in some types of triangles but not others, so the conjecture needs to be refined to be true.

The teacher circulates around the classroom, listens to students' conversations, and interjects key questions for students to consider so they are considering all relevant cases. As she notices students reaching conclusions, she focuses students' attention back to the front of the room where she displays a student's computer screen from one of the groups working on the first conjecture. The group members demonstrate, using the smart board, different triangles they considered and note that the medians will always intersect. Another group member mentions that they searched the Internet and found several sources that named this point the *centroid*. A third member of the group shows how she can demonstrate using coordinate geometry that the medians of any triangle will always intersect in a single point. Some students are unclear about this point related to the proof, and members from the group answer questions to explain.

In this situation, students are clearly engaged in learning. They have tools that enable them to develop conjectures. Moreover, in this community they are encouraged to refine, prove, or disprove the conjectures created by classmates. This activity is more similar to the activity of mathematicians who often begin by exploring a problem space, create conjectures, seek confirming or disconfirming evidence, and build formal justifications that are communicated to peers.

In addition to constant and immediate access to information, with the new wave of Web 2.0 tools, students have the authoring capacity to create, mash up, comment on, and edit content, as well as communicate with people globally. When students are out of school, their digital connectedness and production is pervasive (Lenhart, Madden, Macgill, & Smith, 2007). This phenonmenon has also been documented locally in North Carolina, including with students from low-income families (Spires, Lee, Turner, & Johnson 2008). More than 2.2 billion people use the Internet globally, and more than half of them live outside the US and Europe (Internet World Stats, 2012). These trends are staggering. Perhaps more staggering, however, is that our schools are typically the last places to take advantage of what these digital opportunities afford for learning.

Intensity, Relevance, and Personalization of Learning.

The second condition of the new learning ecology within a 1:1 setting is the potential value of increased intensity, relevancy, and personalization of learning. These new variables come into play as a result of shifting to a more learner-centric dynamic—with potentially higher levels of student performance and achievement. If teachers in 1:1 classrooms teach with the explicit assumption of access, what do they do differently? A central pedagogical shift in the 1:1 class is that teachers empower students to rely on the ubiquitous availability of technology to search and acquire information, critically evaluate information, creatively synthesize information, and generate innovative ideas and products, as well as craft solutions to problems.

In the new learning ecology students engage in what John Dewey referred to as "productive inquiry," which is to "actively pursue a problem, puzzle, point of fascination, object of wonder, or the like" (as quoted in Little & Ray, 2005). The new learning ecology is not simply conducive to productive inquiry but, indeed, demands it. For example, if class time is no longer spent on receiving content solely from the teacher, and if content is readily available and idiosyncratic to each learner, then inquiry becomes the necessary catalyst to transform the learning process so that information found is converted into new knowledge. Likewise, since information is abundant and often provisional until validated, inquiry again becomes essential as the learner sifts, sorts, and critiques information en route to new ways of knowing and problem solving.

Technology tools can serve as an extension of student thinking and learning, with students tapping into endless networks of imagination (Senges, Brown, & Rheingold, 2008). One-to-one environments provide a place to explore ideas, pursue research questions, test hypotheses, compose thoughts, and draw conclusions. In addition, there is a much more varied and robust discursive community—facilitated by the technology—in which these idea s, conjectures, solutions, and questions can be presented and cogitated.

Students are not engaging in activities in which their singular goal is to build up a repertoire of static knowledge and skills to be used later; rather, students become part of an extended participatory community of learners in which the focus is on authentic and productive inquiry and active meaning-making. Active learning in these terms results in significance for students.

Michael Wesch (2008) defined learning as the ability to create significance and distinguished between semantic and personal significance. Semantic significance means understanding that "a word, concept or idea is not just meaningful for what it is, but for how it relates, connects, and contrasts with other words, concepts and ideas." Personal significance, Wesch claimed, connotes that meaningful connections are created in the social interaction with others and through the individual's process of learning to become a successful, contributing member of a community. Although there is a nuanced difference between the two types of significance, both relate to creating significance with information for the individual learner, and in the 1:1 environment both provide the terms for enhancing community.

The 1:1 environment has the potential to promote authentic learning, enabling students to create both semantic and personal significance with academic concepts in the context of the world around them. For example, in an English language arts class, rather than lecturing about Alan Paton's *Cry, the Beloved Country,* teachers can engage their students in organizing a global book club with students in South Africa and India. Based on personalized interests, students can collaborate virtually to create a multimedia inquiry project prompted by themes in the book and the ways in which the themes relate to students' respective lives and cultures. Students focus on different parts of the project based on their interests, existing skill sets, and academic goals.

For example, several students across countries may collaborate and generate an analysis of societal structures that led to apartheid in South Africa and colonization in India. Other students may focus on Paton's unique use of literary devices and explore how they support the themes of the book. Yet another group might compare and contrast the themes and events in the novel to the film *The Power of One*, also set in apartheid-era South Africa. The teacher's role becomes one of facilitator, coach, and consultant who engages in a range of supportive activities that may include anything from making resources available (e.g., literary related content, technology tools, and outside experts) for the students' inquiry projects, to teaching students how to set up a Ning for their

projects to promote worldwide visibility, to challenging students' assumptions about racial prejudice and encouraging them to take an activist stance for tolerance both in their community and on a global stage.

In this scenario, the lesson could be accomplished in a computer lab or with two to three computers in the classroom. If every student has a computer and access to the Internet along with an effective teacher, however, the intensity, relevance, and personalization of the intellectual work become more palpable. In English language arts, the use of the technology to support participatory learning illustrates a paradigm shift from knowledge as didactically transferable content to knowledge as socially processed and constructed. It also reflects a shift emphasizing the importance of "being multiliterate across a range of various dialects, cultural spaces, and semiotic forms" as students engage in learning in which they "communicate across cultures (and sometimes across languages), largely in spaces mediated by technology" (Young, Hicks, & Kajder, 2008, p. 71).

Intensity is derived from the spontaneous nature of active learning, collaborative problem solving, and innovative meaning making that the 1:1 classroom environment inspires. Potentially, the classroom becomes a market place of ideas and one node in a dynamic network of imagination that will motivate and energize students to be curious, productive, and innovative.

Highly Developed Teacher Capacities

Within this new learning ecology, teachers must have highly developed capacities for facilitation, improvisation, coaching, and consultation. Teachers must make a pedagogical shift to accommodate learning that is continuous, changing, and above all, exponential. Prior to the onset of the knowledge society, the role of the teacher was to transmit a relatively stable body of knowledge and skills to students who would then use them for predictable academic and professional careers. Tom Carroll (2007) asserted that "Teaching 2.0" is emerging in response to a 21st-century convergence of forces that includes a knowledge-based global workforce, an evolving understanding of how people learn, and a widespread adoption of collaborative teamwork in the workplace.

Teaching in the modern era is customized to individual learning needs, where teachers and students cocreate meaning and significance out of a wide range of possible learning experiences. They pursue these experiences within a dynamic and fluid new learning ecology. One role of the teacher is to navigate the learning terrain by engaging students in worthy, time-honored concepts and ideas while simultaneously valuing the individual nature of each learner.

Science, obviously, is a discipline demanding highly developed teacher knowledge, including knowledge associated with high-level concepts and the tools and processes that will allow students to develop scientific ways of thinking. For example, a science teacher may design a lesson to teach the concept of deforestation. Deforestation is a major issue in many of the tropical and subtropical parts of the world where forests are being cut down for the value of their trees and also for agricultural uses and housing development. The process of deforestation also contributes to greenhouse gas emissions and, therefore, to the problem of global warming. Although the teacher may not recall all of the detailed facts related to deforestation, they know that this issue is directly related to certain key science content standards and likely to engage her students. She establishes highly functioning teams based on her knowledge of the dispositions of her students, making them responsible for collecting data on a forested region of the world on both the nature of the deforestation (amount of land cleared, where it was cleared, and what the land is

now being used for) over the last 20 years and the contribution of deforestation to greenhouse gases.

Prior preparation allows her to provide the students with an initial set of resource links, but makes the students responsible for finding additional sources of information and justifying the quality and relevance of the information provided. Coaching and guidance by the teacher steers students to likely locations of useful resources in the form of text, numbers, photos, video, and people.

She also helps them apply and continue to develop their ability to make sound judgments in evaluating and synthesizing this information. In addition to the Web browser, the teacher also suggests the use of image processing software such as Image/J (http://rsbweb.nih.gov/ij/) to make measurements on satellite photos, spreadsheets for organizing and graphing data, and various presentation software tools. While she does not know the latest versions of all of these software tools inside and out, she has a sense for the general capabilities and usefulness of these tools and a strategy for helping students help each other (and her) learn the necessary techniques in a just-in-time fashion.

As part of a culminating presentation, students may be asked to report on what alternatives governments and nongovernmental organizations have been pursuing to slow the rate of deforestation. Carefully reading the dynamics of the discussion, she decides to extend the amount of time for presentations when it becomes clear that her students have brought together an exciting mix of data and alternative interpretations worthy of an additional day of deliberations.

Highly Developed Learner Dispositions

A final condition for the new learning ecology prompted by the 1:1 environment is highly developed learner dispositions. Increasingly, learners are described in terms of their dispositions and worldviews, rather than as people who are experts in a particular body of knowledge. Additionally, personalized learning takes place outside of the classroom in a variety of settings and dynamic modes (Bull et al., 2008). The recognition of learning as a social practice that evolves around peoples' interests (Jenkins, Clinton, Purushotma, Robinson, & Weigel, 2006) suggests the need to be intentional about how students are situated in a learning environment.

Ideally, in a 1:1 classroom, the learner will be disposed to the learning process in ways that leverage the ecology of the environment. Learning is viewed not simply as obtaining information from an authority figure, but rather "more as a self-directed process with increasingly greater levels of responsibility and commitment" generated from the learner (Dede, 2009b). Obviously, all students do not enter the classroom with highly developed monitoring skills and academic self-direction intact; therefore, the teacher must take on the role of coach and mentor to assist with the development of these learner dispositions.

A critical stance toward evaluating information and the credibility of online sources is one learner disposition that is essential in the 1:1 classroom. For example, the mere availability of Wikipedia in the social studies classroom in some ways turns upside down generations of assumptions about authority and information. With access to Wikipedia, answers to simple and uncontested questions are likely never to be left unanswered. Wikipedia extends the range of possibilities for students who are seeking information on common topics, but also raises questions about knowledge authority in the classroom.

Wikipedia is at its root a socially constructed resource and a knowledge community, but in most academic circles it is often devalued and afforded little privilege (Chandler-Olcott, 2009; Davidson, 2007). When students have access to Wikipedia, the teacher loses some control over which interpretations about the past are valued and which messages are injected into the classroom culture. Yet, on a simpler level, Wikipedia's open authoring platform results in uneven content quality and requires that students using the resource be more critical in their considerations of content.

Given the conditions that frame Wikipedia as a source of information in the social studies classroom, students need critical dispositions to enable them to make effective use of the information. Although some Wikipedia articles are trustworthy, there are no obvious signs on a Wikipedia article to signal for students when the content should be trusted. Students need to use resources such as Wikipedia with a critical eye and an overriding desire to determine first the trustworthiness of the information. Such an approach to using information in the classroom is quite different than traditional uses of information, where students are told that the information they receive is correct and not subject to challenge.

Being disposed toward self-direction and monitoring will enable students to engage critically not only with Wikipedia information, but also with virtually all resources that are available online. According to Leu et al. (2008), these skills include understanding bias, evaluating reliability, and determining the accuracy of information. Such skills can be taught in the classroom, but students need self-direction and motivation to apply them.

When students use Wikipedia, they cannot rely on the teacher or some other source of authority to vet the materials. Instead, students must take the initiative and apply the critical filters they have learned in the classroom. Furthermore, students will come to school with a wide range of dispositions already in place. Teachers must assess their students' dispositions and provide targeted support for further development in order for their students to take full advantage of the new learning ecology of the 1:1 learning environment.

1:1 Teacher Professional Development

In this section the most current literature on teacher professional development is reviewed, and five promising strategies to be included in 1:1 teacher professional development are proposed. These five strategies take into account the new learning ecology that is evolving as a result of the 1:1 learning environment and can contribute to a new learning ecology for professional development for teachers.

Research-Based Principles for Professional Development

Educators and policy-makers alike have long recognized the necessity for providing high-quality and challenging learning opportunities for teachers to enable them to transform teaching and learning in the classroom. In a recent report, *Professional Learning in the Learning Profession*, Linda Darling-Hammond et al. (2009) asserted that a greater priority should be placed on strengthening the capacity of educators and building learning communities to deliver higher standards for all students. Specifically, they cited countries like Finland and Sweden, where ongoing teacher education is a top priority with impressive results. In these countries, based on the report, students achieve more, teachers are retained in the profession longer, and educators are given more freedom and responsibility for what happens in their school. Analyzing and synthesizing research

results from over the past decade, the authors set forth four principles of effective professional development (PD):

- Be intensive, ongoing, and connected to practice.
- Focus on student learning and address the teaching of specific curriculum content.
- Align with school improvement priorities and goals.
- Build strong working relationships among teachers (pp. 9-11)

Research on PD has demonstrated time and again that occasional workshops do not support substantive change in the way a teacher teaches. Interestingly, Yoon et al. (2007) found that 30 to 100 hours of PD spread over 6 to 12 months is necessary to demonstrate a significant positive effect on student performance. Perhaps even more important than the duration of PD sessions is the quality of the learning experiences within the PD sessions. Teachers need the same types of intellectual challenges and encounters with complex problem-solving scenarios that, in turn, should be designed for students. In fact, one well-known study demonstrated that having teachers experience the same content and learning cycle that they expected of their students led to higher student performance (Merek & Methven, 1991).

In 1:1 settings, professional development and ongoing support is critical for teachers as they redesign, recontextualize, and contemporize their instructional practices to take full advantage of available technologies. Designers of PD for teachers in a 1:1 environment should carefully consider the five unique conditions of a new learning ecology previously discussed, as well as the four major principles that Darling Hammond and her colleagues derived from a substantial body of research.

Teacher professional development comes in many forms. School systems often offer professional development aligned with curricular goals being advocated by the system. Innovative educational programs in North Carolina, like the New Schools Project (http://newschoolsproject.org/page.php), IMPACT (http://www.ncwiseowl.org/impact/), and SAS Curriculum Pathways (http://www.sascurriculumpathways.com/) offer customized professional development that directly supports the types of change processes and related instruction being implemented by the program.

Graduate programs for teachers increasingly are being aligned with state curricular goals, so these contexts can also be considered professional development for teachers. For example, at North Carolina State University's College of Education, we (the authors) have created a graduate concentration, New Literacies and Global Learning(http://www.cednlgl.wikispaces.com), in which in-service teachers come into the program with a compelling question that they address through a project-based inquiry process for the duration of the program. The teachers create a final product of learning, which they display as a multimedia project to be shared in a Design Studio Showcase. Teachers stay connected after they graduate through an online Ning environment as they continue to share their professional insights and challenges.

Regardless of what group is hosting the PD or whether PD is being delivered as individualized, self-paced, online instruction, online video instruction, cohort-based instruction, or face-to-face instruction, five promising strategies need to be considered when working with teachers in 1:1 environments. These strategies can be applied in other learning settings, but they hold particular promise for 1:1 settings since they directly leverage the conditions of the new learning ecology. They have emerged from our

professional development work with teachers participating in the NC 1:1 Learning Initiative (2010). All five strategies leverage the new learning ecology prompted by 1:1 environments:

- Technology, pedagogy, and content knowledge (TPACK).
- Project-based inquiry.
- A new global skill set.
- Performance-based assessment.
- Professional learning communities and networks.

The strategies intersect at different levels within a PD experience. For example, the first strategy is conceptual and is used heuristically; the second, third, and fourth strategies relate to curricular content and pedagogies. The fifth strategy relates to ongoing support systems for PD. The concept of the new learning ecology also applies to ways teachers need to be engaged in professional development through professional learning communities and networks.

1. Engaging Teachers' TPACK

The TPACK model can be used as a theory-to-practice heuristic during professional development sessions with teachers as they are making necessary pedagogical shifts to take advantage of the new learning ecology in the 1:1 classroom. Koehler and Mishra (2008) claimed that effective teaching with technology requires TPACK, or an ability to integrate content, pedagogy and technology flexibly during the act of teaching (see Figure 2). They argued that teaching with technology is a "wicked problem," with solutions being difficult to realize because of "complex interdependencies among a large number of contextually bound variables" (Koehler & Mishra, 2008, p.9).

Central to understanding Mishra and Koehler's (2006) TPACK framework is the capacity to separate the three components (i.e., content, pedagogy, and technology), while at the same time understanding that the components coexist in a dynamic transactional relationship. For example, when a new technology is introduced, it forces teachers to "reconstruct the dynamic equilibrium among all three elements" (p. 18).

Often teachers begin with their disciplinary content as they make TPACK transactional exchanges. As pedagogies and technologies enter the equation, teachers must balance competing demands and carefully consider what is lost and gained when using specific pedagogical approaches and technologies. Ultimately, the pedagogies and technologies should complement one another and intensify students' opportunities to construct content knowledge.

As Harris et al. (2009) revealed, comparatively little work has helped to operationalize TPACK for teachers and teacher educators, especially in terms of how to help teachers develop TPACK. However, the 1:1 environment provides the optimal context for professional development of this kind. In 1:1 environments, teachers often enter the PD experience through the introduction of a new technology. As 1:1 programs mature and teachers acquire more experience in the new environments, the entry points might be content or pedagogy. For most teachers the act of getting the computers and the pedagogical disruption that the computers bring is paramount. For example, with all students having a computer, initially teachers may ask simple questions, such as, "What can I do in my social studies class now that students have continual access to Google maps?" "What can I do in my math class now that all students have access to Excel and

can create a scatter plot?" With each of these examples, content or pedagogy could easily drive the use of technology, but realistically, most teachers will begin with the technology.
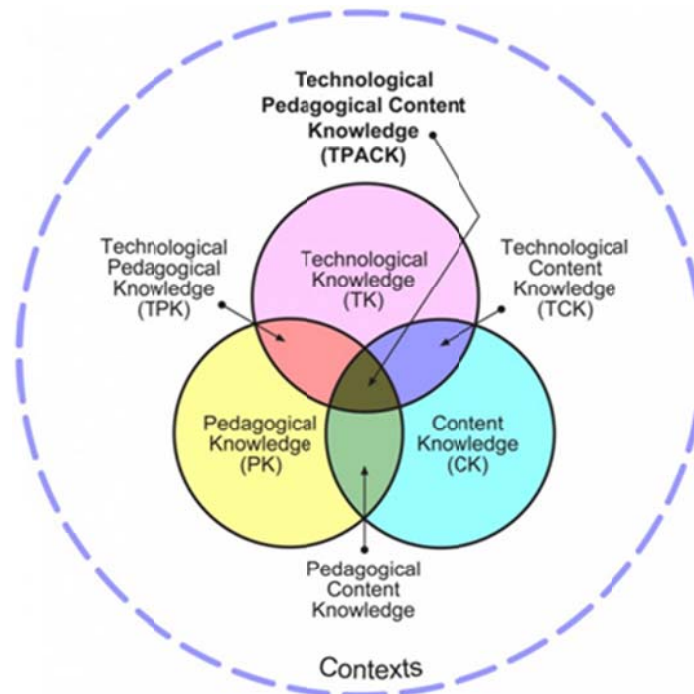

Figure 2. Technological Pedagogical Content Knowledge (TPACK) from Mishra and Koehler (2006). (Image source: http://www.tpck.org)

Within the environment of TPACK-informed professional development teachers have the opportunity to work thoughtfully in concert with their colleagues and PD facilitators to devise powerful strategies for classroom instruction. As Mishra and Koehler encouraged, TPACK-framed professional development can lead to teacher-centered design experiments. Much as with engineering design problems, teachers are working within a bounded solution space where they can learn to assess the capabilities and constraints of a technology and how it furthers a teaching goal. This design process should be overt and a key goal for PD and can take a number of forms. A design experiment can take the form of a series of iterative mini-lessons within the context of a single PD session facilitated by PD instructors.

In addition to addressing TPACK as an integrated theory, different combinations of the key elements of technological, pedagogical, and content knowledge reveal additional details as to how TPACK might inform PD. For example, pedagogical content knowledge (PCK) focuses on illustration and formulation of concepts to be taught and learned. The pedagogical techniques required include an understanding of what makes concepts easy or difficult to learn, combined with an understanding of students' prior knowledge.

Technological content knowledge (TCK) represents the reciprocal relationship between technology and content. Emerging technologies make possible accommodating ways to navigate content. Educators need to be aware of not only their content, but the ways technology can improve the delivery of that content. TCK will often be more discipline specific, looking at how technology shapes information venues and representation types

that will be particularly useful for concept exploration and elaboration. Another way to think about TCK is to consider how it can be applied when looking at how various technology tools might shape the discourse patterns facilitated by these representations.

In standard PCK, teachers learn to create, select, and modify tasks that build on students' current understandings. With TCK, there is the added dimension of identifying where and how to apply technology to particular tasks to further these same goals.

Technological pedagogical knowledge (TPK) often addresses larger influences of technology on teaching and learning that will cut across disciplines. TPK primarily entails a deep knowledge of the components and capabilities of various technologies for use in teaching and learning settings, as well as understanding how teaching might change as a result of using a specific technology. Instructors should be familiar with a variety of tools that are appropriate for particular tasks, able to choose a tool that is well suited for the task, and enact strategies that illuminate the unique affordances inherent in the tool. Teachers' knowledge of how to interweave communication technologies in their planning can open new avenues for participation. This participation can result in more democratic experiences for students, or what Dewey (1927) called associative and continually changing collective experiences, in support of critical and active learning (Lee, 2008).

Acquiring integrated TPACK within a 1:1 environment requires a fundamental conceptual change on the part of the teacher. Generally, conceptual change is considered to be a process that involves a shift in a person's worldview that fundamentally alters how that person develops new knowledge. For teachers, conceptual change may result from formal learning such as what might occur when, for example, a teacher investigates a new theory on cognition. The teacher's knowledge of this theory changes the way the teacher encounters new information and activities, such as planning a lesson on language differences.

Posner, Strike, Hewson, and Gertzog (1982) described the process of conceptual change as challenging central assumptions and paradigms framing an individual's worldview. These worldviews are deeply encoded into mental structures and are often resistant to change. Posner et al. offered four conditions that can facilitate conceptual change, including dissatisfaction, intelligibility, plausibility, and fruitfulness. Other scholars have proposed a host of additional factors that may influence conceptual change, including Pintrich, Marx, and Boyle's (1993) focus on learning contexts, individual goals, and motivational beliefs, Dole and Sinatra's (1998) concern with cognitive and motivational issues, and Gregoire's (2003) emphasis on affective factors.

The new learning ecology that emerges in 1:1 computing environments is a context for conceptual change. Likewise, TPACK is a useful tool to accelerate teacher conceptual change related to technology in the 1:1 classroom. Although they did not measure conceptual change, Spires, Hervey and Watson (in press) found that TPACK can be scaffolded through an inquiry learning process with English language arts teachers. The researchers concluded that, at a minimum, TPACK represents a powerful heuristic for teachers as they negotiate the rich and complex landscape of new literacies with their students. By having teachers routinely reflect on their evolving TPACK and how their pedagogy is changing as a result of technology, the PD goal is that teachers' TPACK will become increasingly sophisticated in support of student learning. Furthermore, the PD experience should yield more of the "grounded models" called for by leaders in the field to help other teachers develop their TPACK, as well (Harris et al., 2009).

2. Engaging Teachers in Project-Based Inquiry

Project-based inquiry is particularly suited to the new learning ecology of the 1:1 classroom, since teachers are challenged to create tasks in which complexity and openness approximate problems in the real world. Students can see the interdisciplinary nature of these tasks and realize that each task may have more than one solution. When students have the freedom to choose different strategies and approaches, they become more engaged in the learning process. Problems that have depth, duration, and complexity challenge students and motivate them toward knowledge creation. When engaged in project-based inquiry, students acquire problem-solving, communication, collaboration, planning, and self-evaluation skills. Likewise, having teachers experience project-based inquiry as an integral part of their PD activities enables them to implement this dynamic process more successfully with their students.

There are numerous models of project-based inquiry, particularized to specific disciplines, but the essential elements of the process can be found in Figure 3:

- Consider ideas and pose questions.
- Gather and analyze information.
- Creatively synthesize information and solve problems.
- Evaluate and revise results.
- Share, publish, and/or act.

As mentioned earlier, project-based inquiry possesses elements of what Dewey referred to as productive inquiry, which "is that aspect of any activity where we are deliberately (although not always consciously) seeking what we need in order to do what we want to do" (Cook & Brown, 2005, p. 62). The challenge for teachers, of course, is to develop the necessary facilitation skills to challenge students to engage in complex thinking and creative and innovative solutions during the process of project-based inquiry.

Adults in their roles both as professionals and citizens face intellectual challenges that are much different than what is typically demanded of students in school. Project-based inquiry within the 1:1 environment provides the opportunity for students to engage in authentic intellectual work (Newman, Bryck, & Nagaoka, 2001). They described the distinctive characteristics of authentic intellectual work as "construction of knowledge through disciplined inquiry in order to produce products that have value beyond school" (p.14). Newman et al. found that students who received assignments requiring more challenging intellectual work also achieved greater than average gains on the Iowa Tests of Basic Skills in reading and mathematics, and demonstrated higher performance in reading, mathematics and writing on the Illinois Goals Assessment Program. They concluded that assignments calling for more authentic intellectual work actually improve scores on conventional tests.

During professional development, it is essential that teachers are immersed in the project-based inquiry process in order to understand how to develop the skill set that involves facilitation, coaching, improvisation, and consultation. Likewise, teachers must experience authentic intellectual work in order to grasp the multilayered facets involved in creating comparable learning conditions for their students.
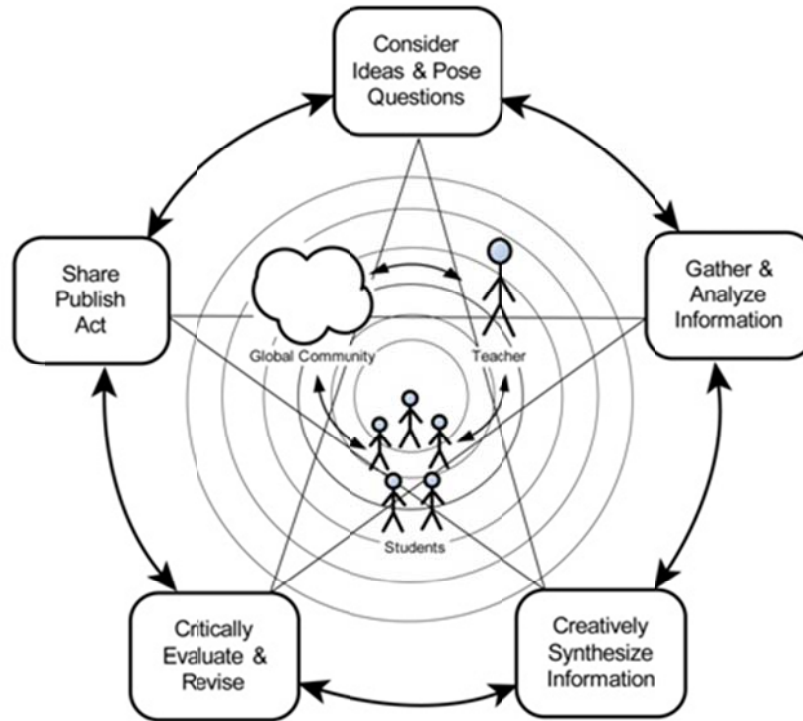
Figure 3. Project-based inquiry in the new learning ecology of the 1:1 classroom.

3. Engaging Teachers in a New Global Skill Set

As teachers engage in project-based inquiry as part of their PD, they must also develop what is being referred to as a new global skill set. Since today's students will be working in a global marketplace and living in a globalized society, in order to succeed and become leaders, they must acquire a far different set of knowledge, skills, and perspectives than did previous generations. They must be able to compete — but also to cooperate—with their international peers. Educational leaders convened by the Asia Society (2007)agreed that the new global environment requires students to master knowledge and skills vastly different from those that were adequate for earlier generations.

This group called for a new global skill set that includes a deeper understanding of academic content, and a set of strategies to enable students to learn to learn, to be creative, and to control their own learning. This set of skills is similar to what the Partnership for 21st Century Skills advocated. The group also called for global literacy, which includes knowledge of other nations and cultures, learning other languages, and exposure to cross-cultural experiences. The best educators around the world encourage students to work in teams to solve problems, deepen their understanding of complex concepts, and increase and share their knowledge. This focus, in turn, helps to generate the skills and dispositions that 21st-century employers demand: adaptive expertise, strong communication skills, creativity, interdisciplinary thinking, and team-based problem solving (Dede, 2009a). The ultimate goal, of course, is for professionals and citizens to be imbued with these valued skills in order to bolster an innovative workforce and stimulate economic development.

Fadel, Honey and Pasnik (2007) claimed that since the US is moving from an information-based economy to an innovation-based economy, "successful intelligence"

(Sternberg, 1997) must be promoted. This concept includes a combination of analytical, practical and creative skills. In an innovation-based environment, a premium is placed on how information is used to imagine new ways to solve problems and create new ways of working. According to the 2009 Program for International Student Assessment results, 15-year-old students in the US on average lag behind industrialized countries in Asia and Europe on problem solving skills in mathematics and science.

The shift toward 21st-century skills is grounded in research conducted by Levy and Murnane (2004). Their research suggested that expert thinking and complex communication are essential for contemporary work, since these are the two areas in the workplace where computers cannot replace human beings. Expert problem solving involves effective pattern matching based on detailed knowledge, metacognition, and the set of skills used by the expert to determine when to end one strategy and try the next. Complex communication involves managing multiple information streams, as well as the capability to interpret subtleties and present convincing arguments.

In an economy flooded with new concepts and invented language, communicating complex information effectively is an increasingly valued skill. Complex problem solving, quick and intuitive decision-making ability, collaboration skills, and resourcefulness are the keys to success in the workplace. The rapid pace of change and the need for continuous learning makes the capacity to learn a highly valued competency, as well.

In order for teachers to become highly adept with the new global skill set, they must be immersed in authentic, challenging professional development experiences that support them in their efforts. For example, if we want students to engage in complex problem solving tasks while collaborating with other students internationally, then PD must be designed to engage teachers in similar types of experiences. Embedding the new global skill set within a project-based inquiry approach achieves the dual function of having teachers focus on authentic intellectual work over time coupled with support from a professional learning community.

4. Engaging Teachers in Performance-Based Assessment

Using project-based inquiry and embedding the new global skills calls for performance-based assessment for students and for teachers. Many educators are using the revised Bloom's taxonomy as a way to design instruction and assessment tasks. Recently, Anderson et al. (2001) adapted Bloom's model to fit the needs of today's classroom by employing more outcome-oriented language, workable objectives, and changing nouns to active verbs. Most notably, Knowledge has been converted to Remember. In addition, the highest level of development is now Create rather than Evaluate.

By replacing Evaluate with Create at the top of the model, there is a desired focus on the cognitive processes of creating, generating, and producing, which is in alignment with 21st-century skills. In the contemporary classroom more time should be spent on creative, authentic intellectual work and less time on remembering, since information is abundant and can be accessed quickly (see Figure 4). Before the Internet, remembering information was more important, since it was not easily retrievable. The inverted Revised Bloom's diagram signifies the importance of the student's intellectual contributions, which occur primarily during analyzing, evaluating, and creating.
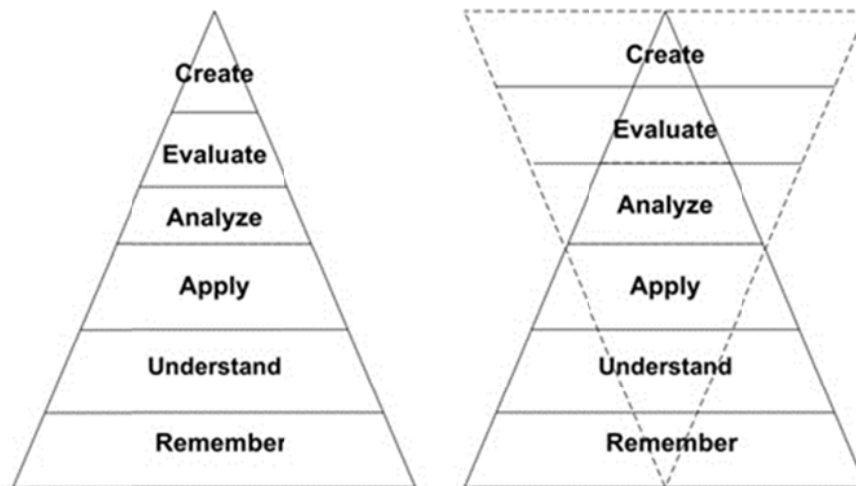
Figure 4. Revised Bloom's Taxonomy (left) by Anderson et al. (2001). The Inverted Revised Bloom's Taxonomy (right) signals the importance of more time and focus on analyze, evaluate, and create—which are important in the new learning ecology.

Performance-based assessment is sometimes characterized as evaluating work in real life, with students assuming responsibility for self-reflection and self-evaluation. The overriding philosophy of performance-based assessment is that teachers should have access to information that can provide ways to improve achievement, demonstrate exactly what a student does or does not understand, relate learning experiences to instruction, and combine assessment with teaching. Fadel et al. (2007) said that assessments should make students' thinking visible so that teachers can see the kinds of conceptual strategies that a student uses to solve problems. Tasks used in performance-based assessment include multimedia products, constructed responses, open-ended problems, real-world simulations, and other authentic tasks. Such tasks are concerned with integrating and using knowledge and complex problem solving. The underlying concept is that the student should produce evidence of accomplishment of learning goals, which can become part of a learning portfolio that demonstrates achievement.

New forms of performance-based assessment are needed at the classroom level to help teachers monitor and improve student learning and at the large-scale system level for accountability purposes. At the classroom level, several traditional ways exist for teachers to record the results of performance-based assessments through rubrics (Hibbard et al., 1996; Stiggins, 1994). Teachers may use a checklist that indicates whether or not certain elements are present in the performances. They may write a narrative report of what was done during each of the performances and then determine to what degree the students met the standards based on the report. Or teachers may use a numerical rating scale to indicate how well a standard was met.

Additionally, a recent surge of interest in designing standardized performance-based assessments has arisen, most notably as a result of the national and international interest in measuring 21st-century skills (Silva, 2008). For example, the recently developed College Readiness and Work Assessment includes an emphasis on what students can do with knowledge rather than what knowledge they have. The 2009 National Assessment of Educational Progress (NAEP) test measured how well students apply their knowledge of science in addition to their knowledge of science principles. This was the first time that NAEP tested application-level knowledge.

Progress is also being made using virtual environments. For example, River City, created by Chris Dede and associates (http://muve.gse.harvard.edu/rivercityproject/), teaches *and* assesses science concepts with middle school students in a virtual world (Dede, 2009b). Students are presented with a problem and required to develop a hypothesis and procedure, test it in the virtual space, and then make recommendations based on their findings. Dede and other researchers are exploring whether virtual environments hold promise for advancing performance-based assessments, especially in the area of complex problem solving.

5. Engaging Teachers in Professional Learning Communities and Networks

Key to developing the new skill set is engaging in appropriate tasks over an extended period with a professional learning community that provides knowledge, support, and encouragement. Attributes of professional learning communities include supportive and shared leadership, collective creativity, shared values and vision, supportive conditions, and shared personal practice. Social networking technologies (e.g., Facebook, Ning, and Twitter) are particularly appropriate as tools for communication, sharing, and just-in-time information within the learning community. Applying the continuous support and feedback of a professional learning community is vital as teachers take on the challenge of acquiring the new global skill set themselves and then being colearners with their students within the new learning ecology of the 1:1 classroom.

Obviously, professional learning communities have been around for some time and have met with varying levels of success. One might assume that schools inherently are learning organizations, but they are often structured in a ways that inhibit collaboration and innovation. Research suggests that professional learning communities can be effective in supporting teachers to acquire important knowledge and skills as school communities to promote relationships that build organizational capacity (Darling-Hammond et al., 2009). These relationships increasingly are sustained through online interactions (Barab, Kling & Gray, 2004; Yang & Liu, 2004) but are also effective as structured, face-to-face interactions (Graham, 2007).

Obviously, with emerging technologies come new possibilities for using virtual environments for professional exchanges and learning experiences. As online professional learning communities become more pervasive, teachers will have increasing options to connect with professionals from around the world to enrich their knowledge and teaching expertise. Teachers will create their own personalized interlocking networks as they sample from a variety of resources and become more sophisticated consumers of online learning opportunities. The professional learning communities and networks will take on new forms and dimensions providing additional opportunities for educators to experience continuous learning within their educational organizations.

Conclusion

Richard Florida (2009) noted that the US economy is in the midst of a fundamental long-term transformation—similar to that of the late 19th century, when people left farms and moved to cities to acquire manufacturing jobs. He, along with numerous others, has observed that today's economy is shifting away from manufacturing toward idea-driven, creative industries. Our schools, and what is at the heart of schools—the teaching and learning enterprise—need to undergo a transformation, as well. The result of this transformation needs to be a type of educational experience and expertise that will not only support but also ignite participation in (and leadership for) an idea-driven, creative economy. Equally important as supporting a new economy is educational experience and expertise that supports a global citizenry.

The 1:1 environment is prompting a new learning ecology, and we have proposed five strategies for consideration to be included in 1:1 teacher professional development. These five strategies take into account the new learning ecology of the 1:1 environment. Equally important, these five strategies can help create a new learning ecology for professional development for teachers—one that supports teaching and learning for the increasingly interdependent global age.

Technological tools and information are not always educationally productive. Educators must provide leadership in creating new models for the teacher to be facilitator, coach, mentor, and even improvisational artist within the new learning ecology—always with an eye on the larger aims and purposes of education. A critical aspect of educational transformation is ongoing teacher professional development aligned with an evolving learning ecology that currently is being prompted by 1:1 learning technologies.

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