13 Mobile Technologies as Mindtools for Augmenting Observations and Reflections in Everyday Informal Environments

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Introduction

For several decades, Jonassen (1996; 2000; 2003; 2006; 2011) has been instrumental in forwarding a vision of technology use that affords new ways of thinking, representing, and visualizing one's experiences for deeper reflection and knowledge construction. His corpus of work around cognitive tools, also referred to as mindtools, frames educational technologies as knowledge construction tools that extend the thinking processes of users, enabling new forms of knowledge representation and task manipulation (Jonassen & Carr, 2000; Jonassen and Reeves, 1996). Mindtools are computer tools that have been adapted or created to extend thinking. His rationale for the concept of mindtools is that even simple, readily-available technology tools, such as databases or spreadsheets, can be powerful intellectual partners for engaging learners in new forms of thinking. Jonassen's mindtools concept is inclusive of general purpose software (such as spreadsheets) as well as designed environments that have been created to facilitate problem solving. Mindtools can include software tools that support knowledge construction and learning-by-design (e.g. programming tools, expert systems, multimedia or web authoring). They can also support semantic organization, dynamic modeling, visualization, multimedia construction, and social networking (Jonassen, 2000). Across the range of approaches and tools, Jonassen (1996) puts forward a unifying concept that "mindtools are cognitive reflection and amplification tools that help learners construct their own representations of a new content domain or visit an old one" (p. 11).

Technology tools can be used to help learners reflect upon and organize ideas and make aspects of the domain under study more explicit and visible (Jonassen, 2000; Linn, 2000). Learner thinking can be made more visible via technology tools that enable the externalization of ongoing understanding (Jonassen 2003; Kafai, 2006), representation of a problem space or conceptual model (Jonassen, 2003), or making connections and comparisons between knowledge and experiences (Collins, 2006). Strategies for

supporting reflection using technology tools take many forms and functions, but our synthesis of the literature codifies three primary activities:

(a) *amplify* observations or experiences in ways that encourage deliberate noticing, capturing, or processing of them;
(b) *organize* the products and processes of explorations to support revisiting and revising them; and
(c) *compare, extend, and explain* what students know, considering alternative criteria, audiences, perspectives, representations, or new data

(Collins, 2006; Land & Zembal-Saul, 2003; Lin, Hmelo, Kinzer, & Secules., 1999; Quintana, Reiser, Davis, Krajcik, Fretz, Duncan, Kyza, Edelson, & Soloway, 2002; Schwarz, Lin, Brophy, & Bransford, 1999).

Reflection can be enacted via strategies and technologies, such as mindtools, that can support learners to articulate, visualize, and think about activities and processes (Jonassen & Reeves, 1996).

Since Jonassen's original theoretical conception of mindtools emerged in the mid-1990s, the technology landscape has changed substantially and perhaps in ways that more readily support his vision of seamless tool use for thinking and reflection. For instance, the size and portability of mobile technology tools, including those that are inexpensive and readily available such as iPods and tablets (and their applications, called apps), enable designers to extend learning opportunities into everyday life worlds of people, untethered from classroom desktops or wired indoor facilities. This opportunity expands the potential range of intentions and experiences that can be amplified for learning. Jonassen has often described the work of Donald Norman (1993) as a foundation for mindtools, specifically his distinction between experiential thinking (automatic thinking about ones experiences with the world) from reflective, or more deliberate, thinking. Jonassen's vision was that technology, specifically mindtools, could be a connector between experiential and reflective thinking. Portable, wireless technology tools more readily and immediately support this pairing of experience and reflection, as they can be brought to bear directly in the user's experiential world.

Our discussion here applies the mindtools concept to three cases of everyday learning with informal mobile technologies (i.e. digital cameras, iPods, iPads, smartphones). This shift in context from formal to informal is a departure from the prior research and theory on mindtools for classroom use. The everyday world offers a rich context for learning and extending what is learned in school, yet learners are rarely supported to make such connections, at least in any systematic way. By everyday, we are referring to experiences that routinely occur in daily life that are familiar, informal, and often tacit. Numerous sociocultural studies have tried to characterize differences between the types of learning that occur in formal educational contexts and the world outside schools. For instance, studies of activities such as carpet laying, farming, candy selling (Carraher, Carraher, & Schliemann, 1985;

Saxe, 1991), shopping (Lave, 1988), and game playing (Nasir, 2002, 2005) have examined the connections between mathematics learning and cultural practices associated with activity. These studies recognize that knowledge use and learning occur outside of designed, pedagogical settings. More so, the expression and use of knowledge in these settings rely on tools and artifacts situated in the environment, leading to norms, values, and conventions that generally look very different than those found in designed education contexts.

Anchoring learning in real-world experiences or authentic problems (Jonassen, 2004) potentially enhances the likelihood for discovering the relevance of how and why knowledge is useful (Bransford Brown, & Cocking, 2000). For instance, being able to reflect on the environmental science underlying bee pollination in one's backyard requires intentional observations and interpretations of the surroundings through a scientific lens. Recent mobile computing devices allow for these sorts of investigations and support learners to explore their everyday experiences and use them as objects for knowledge construction (Pea & Maldonado, 2006). In the BioKIDS curriculum, for instance, students used handheld computers to explore their schoolyards, collecting and observing various animals, in order to develop basic understandings of organisms, environments, and interactions between the two (Huber, 2003). Similar biodiversity concepts could be studied with simulations, video clips, and other media (Reiser, Tabak, Sandoval, Smith, Steinmuller, & Leone, 2001), but the use of local, familiar environments and animals may help students better grasp the relevance of the biological theories. Similarly, handheld computer devices, in conjunction with palm-enabled probeware, have been used to enable learners to collect and analyze data from the field (Soloway, Grant, Tinker, Roschelle, Mills, Resnick, Berg, & Eisenberg, 1999), which could include backyards, streams, or parks. The mobility of these devices enables new ways of exploring familiar, everyday experiences, where people learn with, not from, mobile devices, resulting in "an intellectual partnership with the computer is that the whole of learning becomes greater than the sum of its parts" (Jonassen, Carr, & Yeun, 1998, p. 14).

Supporting learners to look at their surroundings with diverse perspectives, including those used by professional practitioners, is a goal of informal educational environments such as outdoor nature centers, where portable technology tools are being explored (see e.g. Liu, Peng, Wu, & Lin, 2009; Rogers, Price, Fitzpatrick, Fleck, Harris, Smith, Randell, Muller, O'Malley, Stanton, Thompson, & Weal, 2004). Our work, which will be the focus of this chapter, seeks to extend the concept of mindtools to include mobile technologies that are integrated into everyday places or experiences for more deliberate reflection and learning. The remainder of this chapter presents three cases of designs for learning outside school, that fall into two broad categories of mobile tools (digital cameras and augmented reality for iPads/iPods) that have been used as technology tools to enable reflection on everyday events, experiences, and places. The first category exemplifies digital cameras as mindtools to capture images of places or experiences, and to organize these images as artifacts to compare, extend, and explain their thinking. The second category is focused on augmented reality as mindtools to amplify observations within a place to encourage deliberate noticing or engagement of disciplinary-relevant practices.

Digital Cameras as Tools to Capture Images as Artifacts for Reflection

In this section, we present two examples that illustrate how Jonassen's framework of mindtools can be extended into everyday places and contexts in support of knowledge construction. Attendant to Jonassen's assumptions of using technology as a tool for thinking, reflection on one's experiences can be better enabled if they are captured in some form – audio, video, written diaries or logs – and used as concrete examples that facilitate shared argumentation, discussion, and reflection. Images collected from videos or cameras provide ways to capture a range of experiences that can be analyzed, compared, or explained (Collins & Brown, 1988). Captured behaviors and experiences allow for reflection (Schön, 1983) as well as being a conversational prop (Brinck & Gomez, 1992; Roschelle, 1992). Asking people to deliberately capture aspects of their experiences often leads them to reflect on observed events as they unfold. Using an expressive medium may somewhat interrupt normal, everyday activities, prompting a photographic eye towards otherwise ordinary events or objects that can be organized and expressed in new ways.

Using digital cameras as tools to document learners' experiences allows them to explore concepts in terms of their experiences. Furthermore, mobile devices such as still and video cameras, potentially become mindtools to capture and represent *images as data* (Smith & Blankinship, 2000). For instance, Rubin's use of video as a form of laboratory instrument (Rubin, 1993) enabled students to film events in the world and analyze them scientifically. Students could capture video of classmates running a race and use the footage to understand the properties of motion (Rubin, Bresnahan, & Ducas 1996; Rubin & Win, 1994). Similar uses of video to capture and reflect on performance have been applied to dance (Cherry, Fournier, & Stevens, 2003), kinesiology (Gross, 1998), visits to science and art museums (Stevens & Hall, 1997; Stevens & Toro-Martell, 2003), classroom learning (Goldman-Segall, 1997), and surgical theaters (Nardi, 1996). All of these examples share the mindtool purpose of extending and amplifying thinking, with the goal of helping learners qualitatively represent the problem space (Jonassen, 2003) and reflect on their observed experiences. In this way, images captured from digital cameras (a) promote reflection on activities that might normally be tacit, (b) build connections between disciplinary practices and the experiential world, and (c) highlight aspects of a developing theory that warrant further investigation (Jonassen & Reeves, 1996; Land, Smith, Park, Beabout, & Kim, 2009).

Case 1: Digital Cameras as Tools for Reflecting on Nutrition Concepts

We have previously explored a series of projects with young children (Kindergartners through fifth graders) in multiple contexts (e.g. health classrooms, after-school programs) that utilized digital cameras to visualize, analyze, and reflect on everyday food choices (Land et al., 2009; Park, 2007). Typical health and nutrition standards at the primary school level involve identifying the different food groups of the food pyramid, serving sizes, and nutrients. Our projects sought to emphasize learning about nutrition concepts using the everyday eating experiences of kids – those that are consistent with adult and professional practices around monitoring and improving health and nutrition.

We provided each participating child with digital or disposable cameras to take home and create records of their food choices for a period of time (e.g. three days to one week). The children used these photographs as data to answer a driving question, "How healthy is the food that I am eating?" Using the actual photographs that they took of their food choices, children learned about the different food groups, identified whether they were eating a balanced diet according to USDA-suggested dietary standards, analyzed fats, sugars, and whole grains, and provided justification for whether the photographs of their meals represented a healthy diet. From these analyses, they identified changes they could make to their typical diet.

In order to support learners to represent knowledge as a "mindful task" (Jonassen & Reeves, 1996, p. 696), we designed a multimedia construction activity (Jonassen, 1996) using photo-journals for them to analyze their photos, articulate their beliefs about the healthiness of their food, and to justify these beliefs using basic nutritional concepts. One aspect of the photo-journaling prompted the children to make nutritional analyses of each photographed meal, considering whether the meals were healthy and why they believed this to be the case (Park, 2007). Using digital photographs as media artifacts supported student discussions with each other around their photographs. Furthermore, the children shared their photographs with their parents, and together they could identify specific strategies to improve the healthiness of their food choices, thus crossing the boundaries between home and school activities. Using the photographs to develop multimedia artifacts, the children constructed organized knowledge representations of their data (food choices) that could be revised and revisited using new information and perspectives.

Our research found that using digital cameras as cognitive tools supported learners to reflect on differences between what they were eating and what they believed they were eating (Land et al., 2009; Park, 2007), lending support to Jonassen's premise that mindtools serve an important role as a connector of experiential and reflecting thinking (Jonassen, 1996; Jonassen & Reeves, 1996). The portability of the digital cameras readily enabled this pairing of experience and reflection. Comparing their own choices with USDA criteria and categories of healthy food choices prompted surprise and reflection as a result of discrepancies they noticed between their photographs and their personal beliefs about their dietary choices. This suggested that capturing and analyzing experiences through self-taken photographs helped learners ground new knowledge of nutrition in their experiences, potentially leading to greater awareness and reflection.

Case 2: Digital Cameras as Tools for Reflecting on the Past and Present of a Place

We also explored the use of digital cameras as tools to reason about history. In particular, we felt it would be useful to have learners study their local communities and consider ways in which they had changed over time. Most communities have gone through large changes in the past hundred years. For instance, city planning has changed with advances in transportation, from horse-drawn carriages to cable cars, to automobiles and subways, and these changes alter the ways that people have moved and lived. Trying to understand a city's design can lead to an increased awareness of the intricacies of the urban environment, what is designed and what is natural (Stilgoe, 1998). More so, everyday travels through a city could lead learners to generate and evaluate hypotheses about its development.

History textbooks typically focus on facts, events, and the names of people rather than the questions, decisions, and heuristics that expert historians use in their work (Paxton, 1999; Voss and Wiley, 2006). Being a skilled historian involves collecting, integrating, and questioning evidence conveyed through multiple sources (Rouet, 1997; Wineburg, 1991), but these skills are not always emphasized in history curricula. As a result, students often associate history with knowing facts and conclusions rather than their underlying justifications and arguments (Voss & Wiley, 2006,).

The mindtools emphasis on meaningful learning through problem solving (Jonassen, 2006) influenced the development of a learning environment called *Image Maps* that connected personal photographs with archival images as a way to understand a community's history. We designed multimedia construction tools that allowed students to trace the development of buildings or locations over time and generate hypotheses about how and why architectural changes were made (Smith & Blankinship, 2000). Approximately 1,000 historical images of Cambridge, Massachusetts along a two-mile route were identified and digitized. Along the route are two major universities (Harvard and MIT) and two major commercial zones (Central and Harvard Square); these targets were chosen for their historical significance and the availability of numerous photographs from the 1890s to the present. Once these images were scanned, students created multimedia evidence to support and refute claims about the evolution of the urban landscape (Jonassen, 2000).

The intention was for students to walk up to a building and have it reveal photographs of its history, much like the Augmented Reality app *Street*

Museum allows users to do on a pedestrian route through downtown London. As students explored and photographed the community, the camera's latitude, longitude, and orientation were captured and inserted into the digital image file. When student photos were uploaded into our application, their position data was matched with historical images stored in a database. If a student took a picture of the newsstand in Harvard Square, the system would retrieve and display historical images of that location taken from the same location and angle. In a sense, the camera and retrieval software acted as a "time machine" (technical details can be found in Smith, 1999); students photographed the present, and the computer returned images of the same location from the past (see Figure 13.1).

The learning environment acted as a mindtool by helping students to make sense of the pictures using multiple representations and perspectives (i.e. historical, architectural, urban planning) (Jonassen & Reeves, 1996). Students began by annotating their pictures with features that changed over time. For instance, some students might have focused on transportation, marking some images with *horse-drawn carriage* tags, others with *automobile* tags. Another group of students might be interested in land use, describing buildings using tags like *commercial* or *industrial* or focus on changes in Cambridge fire stations. Students used labels to compare images, reflect on similarities and differences, and create temporal chains to describe their observations.

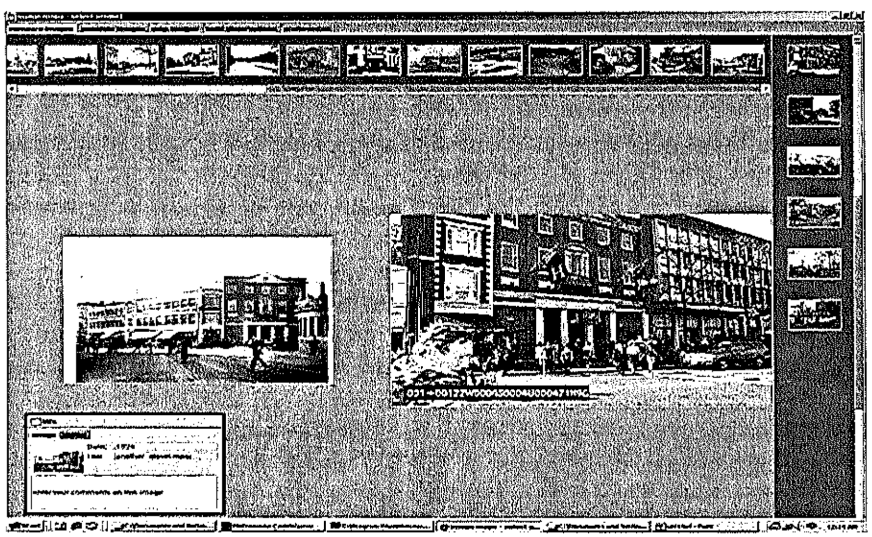

Figure 13.1 An early version of *Image Maps*. Thumbnails along the right side are pictures taken by students. Selecting one of these brings up the thumbnail at the top of the screen, historical images linked to same location. The large image at right center is the student's photograph; the image at left center is an expanded view of a related historical image.

These chains connected historical and student-taken photographs to explain particular aspects of community change. Figure 13.2 shows a set of chains generated by a group of students to illustrate a relationship between traffic and parking over time.

One important characteristic of the image repository is its use of student-collected photographs to drive student inquiry. The goal was to lead students through various tasks, scaffolding the process of observing historical photographs and generating hypotheses about community change.

Augmented Reality as a Tool for Scientific Observation

Another mobile application of technology we have used to support problem solving related to scientific observation in everyday contexts is Augmented Reality (AR). AR combines elements of a real-world physical space with virtual material (e.g. text information, videos, audio, gaming scenarios) in real time (Feiner, Macintyre, & Seligmann, 1993; Rogers et al., 2004). Popular augmented reality environments are available as commercial apps on most mobile devices. For instance, one popular commercial app is *StarWalk*, which enables users to point their mobile devices to a particular location in the night sky and see real-time images of constellations, planets, and stars overlaid onto their device screen. AR also uses Quick Response (QR) bar codes and/or global positioning system (GPS) coordinates to trigger the relaying of such information.

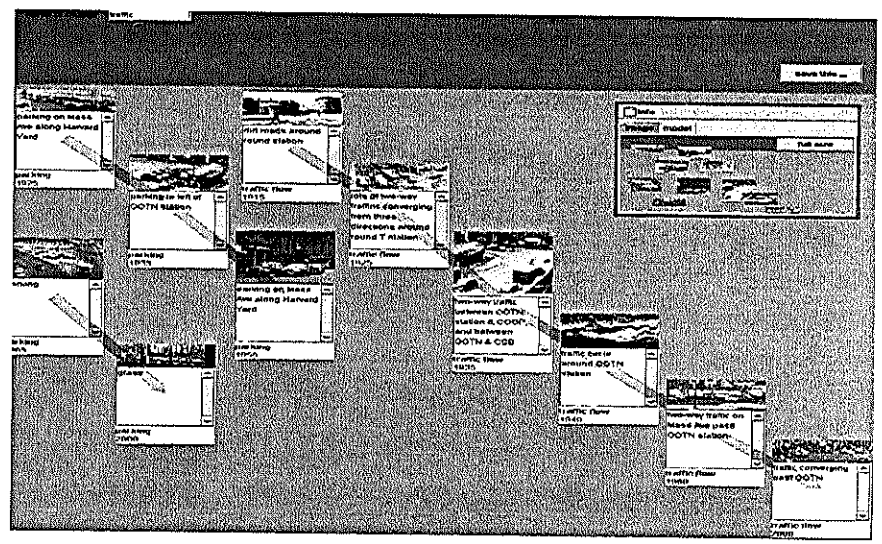

Figure 13.2 An early version of the *Image Maps* timeline tool. Students used this to link historical photographs and explain how and why they were depicted events that were changing over time.

The 2011 Horizon Report (Johnson, Smith, Willis, Levine, & Haywood, 2011) suggests that augmented reality offers "strong potential to provide both powerful contextual, *in situ* learning experiences and serendipitous exploration and discovery of the connected nature of information in the real world" (p. 17). For instance, students can carry mobile, wireless devices through a real-world context and "engage with virtual information superimposed on physical landscapes (such as a tree describing its botanical characteristics or a historic photograph offering a contrast with the present scene)" (Dunleavy, Dede, & Mitchell, 2009, p. 8). In this way, augmented reality apps on mobile devices can serve as tools for reflecting on real-world experiences on demand and within a contextually-rich context outside of school.

Case 3: Using AR to Support Scientific Observations in an Outdoor Nature Center

Land and Zimmerman used AR in a project entitled *Tree Investigators* – where learners explored deciduous and evergreen trees – comparing local trees to each other, as well as to non-native species to make decisions about the scientifically relevant aspects of the garden to make an identification (Land, Zimmerman, Murray, Hooper, Yeh, & Sharma, 2011). Research has found that when learning to make scientific observations, novice learners have to see in new ways (Eberbach & Crowley, 2009); or in problem-solving terms, novices face seasonally dynamic and scientifically situated problems of understanding what is relevant to the situation (Jonassen, 2000). In this sense, learners faced two kinds of authentic science problems, which mapped onto Jonassen's problem-solving processes from a typology (2000):

- strategic performance – applying tactics from science that are relevant to a situation; and
- decision making – identifying and comparing evidence to best fit a problem with appropriate justification.

With the aid of the *Tree Investigators*, learners applied these two problem-solving processes to support their knowledge building and reflection. Learners needed to (a) *apply* tactics from science to identify a tree, (b) *diagnose* which aspect of the tree to focus on to show the biological diversity of trees, and (c) *decide* about the differences between evergreen and deciduous trees to aid in identification. The goal behind *Tree Investigators* was to support youth's knowledge building in the life sciences, in the sense that the AR materials encouraged youth to have a deliberate focus on the scientifically-relevant aspects of the trees. In this way, the AR provided learners with additional resources to engage within the physical space as scientists. The blend of the technology augmentations and key elements from the outdoor learning space changed the activity by combining aspects from two settings (technological and physical) into one.

In this example, the youth's interactions using the technology are mediated in two main ways. First, students' physical observations of eight different trees with text and images were supported through QR (Quick Response) codes (see Figure 13.3) that were indexed to specific trees to highlight variations in physical characteristics. The AR materials focused students' observations on these variations and encouraged them to make additional comparisons in order to highlight species' similarities and differences. In addition, *Tree Investigators* used Microsoft™ Tag Reader to bring specific web-based content to an iPod or iPad that was uniquely relevant to the garden site being explored and to the community. Comparisons, for example, were made between the heights of trees and nearby buildings. Learners were prompted to compare the bark of the tree in front of them to the bark of the tree to their right.

The science content we layered into the garden space via AR tools included three main characteristics of the tree being investigated: (1) leaves/needles, (2) fruit elements, and (3) bark features (see Figure 13.4). Where possible, we augmented images and information that were not directly perceptible to the students at that time (e.g. fall leaf colorings, spring flowering). Organizing the content in this structure served as an intentional scaffold to reveal to students a method of observation of tree species that could help them identify similarities and differences. The link and interface structure suggested a common set of connected ideas that could be applied across instances (Jonassen & Carr, 2000; Quintana et al., 2002).

We also augmented the garden space by creating a "tree mystery" narrative as a context for applying their newly-refined observational practices about trees. Students were told that they were going to help determine the species of a new tree that was donated to the arboretum. Students received clues to figuring out the mystery tree via large AR markers that displayed an

Figure 13.3 QR code for accessing context-specific information in the garden.

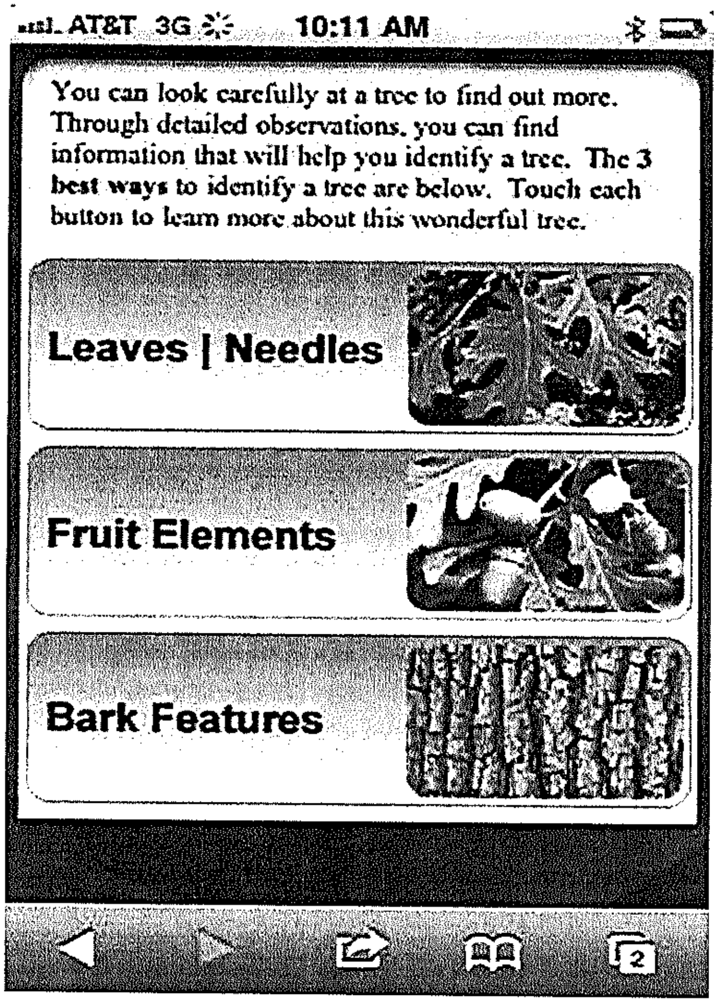

Figure 13.4 Tree characteristics that were augmented and accessed with Microsoft™ Tag Reader.

image of one of the characteristics of the mystery tree. When the AR markers were held in front of a webcam, the content associated with that marker (i.e. a unique biological feature of the mystery tree) was displayed on the computer screen. Students used a commercial US Trees app to help narrow their search by answering dichotomous key questions. Taken together, our goal was to use AR as a tool for revealing observational methods used by scientists to look at tree species and to facilitate the development of children's own observation skills of the relevant aspects of the local outdoor context.

Conclusion

Mindtools was a concept that grounded learner-centered designs across these three case studies of designs for mobile technologies outside of school (Jonassen & Reeves, 1996). The examples in this chapter all support youth and families in articulating their ongoing understandings, comparing performances or phenomena, and explaining understanding in cohesive ways. Through these cases that focused on learning about disciplinary content connected to everyday places, mobile devices served as mindtools by helping learners connect their experiences with authentic practices, problems, and contextualized knowledge. The success of these three cases suggests that the use of mobile technologies as tools to extend thinking has potential to help learners make deeper connections between their everyday lives and knowledge construction.

Our efforts are intended to provide a starting point to suggest new directions for the application of Jonassen's foundational work on cognitive tools. We see the need for educational researchers and designers to explore tools and frameworks that can transform a *physical* place into a *learning* space by either (a) capturing elements of a place or experience that can be used for further processing, extension, or knowledge construction; or (b) layering data, perspectives, or scaffolds into a physical place in real time to augment how learners can engage the space in ways otherwise conceptually inaccessible to them.

Although Jonassen's mindtools approach was originally intended for, and applied, in school contexts, researchers and designers working with informal environments can adapt the construct to support learners' reflection and articulation. This adaption to learning outside of schools becomes a design imperative to address the needs of the full educational system. For example, Bransford, Brown, and Cocking (2000) noted that students spend only 14 percent of their time in school, but spend roughly 53 percent of their time in the home and community. The informal learning contexts of home, recreation, and community life are largely untapped by designers, researchers, and educators. By applying Jonassen's work into new technologies and new spaces, educational researchers can address questions of how to mobilize people's rich, informal experiences and everyday contexts in their understanding. The theory and application of Jonassen's frameworks for meaningful learning provides a basis for conceptualizing and designing technology tools to support knowledge representation and construction in real places and contexts. The concept of a mindtool is a valuable method for aiding designers to connect individuals' authentic, everyday experiences with systematic reflection and articulation of them.

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14 Mindtools for Argumentation, and their Role in Promoting Ill-Structured Problem Solving

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Introduction

Helping students gain skills in problem solving is a key goal in twenty-first century education (Kuhn, 2007; Warschauer & Matuchniak, 2010). No longer is it enough to simply have a body of accumulated knowledge; rather, one needs to be able to apply knowledge to solve problems (Carnevale & Desrochers, 2003; Casner-Lotto & Barrington, 2006). But the type of problem solving students need to learn is not represented by the classic story problems that many remember from mathematics class. Determining when two trains travelling in opposite directions will meet is not an authentic problem in that it does not represent the kind of problems people face in the real world. As Jonassen (2000) noted, the kind of problems encountered in the real world are ill-structured problems, which cannot be solved by applying a simple procedure or with only the presented information. As such, students need to address ill-structured problems in school (Jonassen, 2000). Simply providing students with an ill-structured problem and expecting them to solve it is not productive.

In this chapter, I explore methods of supporting a critical process involved in ill-structured problem solving – argumentation. First, I explore ill-structured problems, and their role in education and the twenty-first century workforce. Then, I explore the connection between ill-structured problem solving and argumentation. Next, I explore methods for helping students gain skill in argumentation, including scaffolding (as mindtools). Then I discuss controversies in the literature on scaffolding argumentation. Finally, I look forward and discuss argumentation and problem solving and their role in the future of educational technology.

The Need for Ill-Structured Problem-Solving Ability

David Jonassen is a key figure in the emergence of ill-structured problem-solving ability as a focus of education. As he wrote about the importance of ill-structured problem solving, researchers listened, and cited Jonassen's work extensively. According to Google Scholar, as of March 21, 2012, Jonassen has 64 works that have each been cited at least 64 times, including