# Assessing Teaching Skills with a Mobile Simulation

David Gibson
*Curtin University, Australia*

## Abstract

*Because mobile technologies are overtaking personal computers as the primary tools of Internet access, and cloud-based resources are fundamentally transforming the world's knowledge, new forms of teaching and assessment are required to foster 21st century literacies, including those needed by K–12 teachers. A key feature of mobile technology applications is the integration of cloud-based resources on handheld devices supporting several computing and communication functions. Mobile technologies' unique affordances for teaching and assessment—especially automated, high-resolution, distributed data collection methods and analysis engines—can create unique distributed task environments for learning and assessment. SimSchool is an example of a computer simulation designed for teacher education that utilizes mobile computing affordances. Mobile simulation-based measurement of teacher knowledge and skills implemented in simSchool contains lessons that may be broadly applicable to other interactive and adaptive educational applications.*
*(Keywords: Mobile simulation, games, computer simulation, automated assessment, cloud computing, simSchool)*

Measuring teaching skills is of great interest in teacher education. The Council of Chief State School Officers (CCSSO), for example, recently updated its Interstate Teacher Assessment and Support Consortium (InTASC) Model Core Teaching Standards "in response to the need for a new vision of teaching to meet the needs of next generation learners" (CCSSO, 2011) through its Interstate Teacher Assessment and Support Consortium (InTASC. Unfortunately, the word mobile does not appear in the update, nor does the word simulation. Nevertheless, enthusiasts of technology in education can celebrate the significant progress made since the original InTASC standards in 1992, when the word technology was mentioned only twice as a kind of "material" to enhance learning. Happily, technology is now put forward in many other roles: as a tool to engage students; to ensure access to knowledge; to support content and skill acquisition; for assessment; for modeling ethical and safe practices, such as citing literature and respecting others; engaging people outside of the classroom; and for personal professional growth, including exploring how new and emerging technologies can promote student learning.

Today, however, we stand at a watershed moment in digital technologies, which has not yet been captured in key standards of practice for teachers. The Internet (which is also not mentioned in the updated 2011 InTASC update) has changed much about our global society. Some would argue it has changed nearly everything (Friedman, 2005). Computational thinking, a concept that in part captures the emergence of visualization and simulation techniques and computers as agents in knowledge building, also points to the wholesale shift of the scientific culture toward complexity sciences made possible by the vastly increased computational power now in our hands (Thagard & Litt, 2008). For these and additional reasons outlined below, the topic of teacher education and mobile technologies—skilled teachers who use, learn, and teach with mobile technologies—is critical to the future of education.

To be clear, the narrative's mention of mobile technologies refers not only to devices such as smartphones, but also to processes and capabilities that are largely independent of devices, such as cloud computing. The magnitude of this definition needs to be emphasized. In the future, the devices will all be different, but the principles of mobile technology will not change. If something is *mobile* as this article uses the term, it means you can easily take it with you; it is untethered. Information and computing power is everywhere you need it, accessible anywhere at any time. Mobile technologies give access to everything that can be created with and by digital information. Mobile technologies thus let us interact with literally everything digital that can be communicated wirelessly to any kind of handheld device (i.e., all information in digitized forms). By the time of the next update to InTASC, several additional words and phrases will hopefully appear, including *Internet, mobile technologies, games, simulations,* and *computational thinking*. If they do not, schools may be seen as largely irrelevant for 21st century learning (Aldrich, 2005; Bjerede, Atkins, & Dede, 2010; Gibson, Aldrich, & Prensky, 2007).

The following sections address with more detail the questions "Why mobile?" "Why simulation?" and how a simulation-based teacher assessment system measuring higher-order skills holds lessons for future mobile applications that are designed to be interactive, adaptive, and useful for teaching and learning.

### *Why Mobile?*

Mobile technologies are at the leading edge of personal computing. As evidence, for example, sales of smartphones passed sales of personal computers in February 2011 (Poeter, 2012), and mobile devices in general are expected to overtake personal computers as the primary means of reaching the Internet sometime in 2013 (Sadauskas, 2012). As a result of these watersheds, students are now increasingly likely to use a mobile device to learn. A recent study found that half of middle school students have a smartphone, and one-third use a mobile device to do their homework, even though only 6% of students are allowed to use the devices while in class (Kristis & Glauber, 2012). This growing gap in the use of mobile technologies in school and at home is evidence of a need for teacher training to "go mobile" in order to provide teachers with the knowledge, skills, and tools that their students are increasingly taking for granted as part of life and learning.

Mobile technologies are the leading edge of personal communications as well as personal computing. The integration of media, data, and social communication, plus free access to powerful tools for producing messages and images, has led to new roles and expectations for an individual's active ability to participate in shaping culture and knowledge (Jenkins, Purushotma, Clinton, Weigel, & Robison, 2006). With a mobile device in hand, learning, shopping, getting and giving advice, staying up to date on the news, and entertaining as well as being entertained are available anytime, anyplace—except in the untransformed classroom. The cultural shift toward ubiquitous active participation in knowledge and culture building implies new opportunities for learning and is further evidence of the need for teacher education to embrace mobile technologies.

Mobile technologies support several key opportunities for learning (Lemke, Coughlin, & Reifsneider, 2009):

- They encourage anywhere, anytime learning, allowing for situated learning and bridging the gap between school and other environments. Context-aware mobile learning, which ties learning to place and embeds virtual information and experiences, is a particular theme here.
- They reach underserved children, providing new learning opportunities to individuals, communities, and countries that are particularly challenged socially or geographically.
- They improve social interactions deemed essential for 21st century success, such as collaboration and language learning.
- They fit with many learning environments, both in classroom settings and in informal learning environments, such as museums.
- They enable a personalized learning experience, facilitating the one-to-one paradigm and targeting learning to individuals.

With the shifting ground of digital culture empowered by the new affordances of mobile technologies and several attendant new opportunities for learning, the requirements for becoming a literate participant in society have changed. As a result, new forms of teaching powered by technology are needed (U.S. Department of Education, 2010). The main themes of technology-powered teaching emphasized here involve:

- Distributed resources and real-world challenges
- Learner choice and self-direction
- Embedded coaching and assessment

For these reasons, teacher education programs need to include mobile technologies in their preparation program, as well as in K–12 outreach, service, and research programs supporting continuing professional growth.

### Why Simulation?

Simulations and computational model-building are leading methods of science that are transforming from tools of primarily science and mathematics disciplines to all areas of knowledge (Gibson, 2012; Wolfram, 2002). Key to a digital simulation is an underlying model that allows testing new ideas and alternatives, a process that makes games and simulations promising subjects for research into technology-based teaching, learning, and assessment of 21st century skills (Mayrath, Clarke-Midura, & Robinson, 2011). Simulation scenarios create data and allow multiple hypotheses. When delivered as a mobile application designed to document performance over time, it becomes possible to trace a user's actions—indicators of their decisions, knowledge, skills, and attitudes—at high resolutions of both space and time. For example, in the simSchool simulation described briefly below, data is collected every 10 seconds across as many as 300 variables, giving rise to a data file of 18,000 records for a single 10-minute teaching performance by an individual (Gibson, 2004a). Simulations also can take advantage of time dilation. For example, teaching for 10 real minutes in simSchool simulates 60 minutes of class time. The shortened experimental time allows multiple teaching attempts and many cycles of trying, seeing what happens, reflecting, re-planning, and trying again. These features of simulation allow one to test and compare results from several hypotheses and perspectives.

Simulations thus empower and heighten learning through action and reflection (Argyris & Schoen, 1974) in a way that is consistent with the principles of free play and experimentation (Huizinga, 1955), leading to demonstrated impacts such as increased confidence, acquisition of new skills, and changes in mental models and attitudes. See, for example, Knezek, Fisser, Gibson, Christensen, and Tyler-Wood (2012) for a summary of research on the following impacts of the simSchool simulation:

- Provides practice in a safe environment (e.g., virtual children cannot be hurt by mistakes and experiments that help a teacher develop)
- Lowers the cost of field training (e.g., replaces placement costs, saves travel and time, and ensures an equitable distribution of mentoring experiences)
- Develops teaching skills (e.g., differentiation of instruction, understanding student records, psychology of learning, student learning characteristics)
- Influences attitudes about teaching (e.g., changes the mental model of

locus of control from external factors affecting a child's learning to a teacher's self-efficacy)
- Exposes teachers to learner diversity (e.g., develops awareness of gender, race, learning differences, and how psychological states affect learning)
- Supports new research on teaching (e.g., allows new research questions, collects data, and allows new ways of analyzing data)

Teacher education programs that have an interest in using simulations and mobile technologies to deliver more effective teacher development experiences might therefore benefit from the affordances of alternative assessment methods with mobile technologies.

SimSchool is a cloud-based simulation, playable on mobile devices, that is designed to promote pedagogical expertise by re-creating the complexities of classroom decisions through mathematical representations of how people learn and what teachers do when teaching. The model includes research-based psychological, sensory, and cognitive domains similar to Bloom's Taxonomy of Educational Objectives (Bloom, Mesia, & Krathwohl, 1964). However, in simSchool, these domains are defined with underlying subcategory factors that reflect modern psychological, cognitive science, and neuroscience concepts. For example, the Five-Factor Model of psychology (McCrae & Costa, 1996) serves as the foundation of the student personality spectrum. This model includes the characteristics of extroversion, agreeableness, persistence, emotional stability, and intellectual openness to new experiences. For each of these five factors, a continuum from -1 to +1 is used to situate the learner's specific emotional processing propensities, which can shift as the context of the classroom changes. A simplified sensory model with auditory, visual, and kinesthetic perceptual preferences comprises the physical domain. For each of these physical factors, a scale from 0 to 1 represents the simulated student's strength and preference in a unified model (e.g., a setting of 0 means that the simStudent both cannot see and has no preference for visual information, and a setting of 1 indicates that the student can both see and has a high preference for visual information). A flexible single factor is used to represent a specific academic domain. Together the physical, emotional, and academic factors represent salient elements of classroom teaching and learning (Gibson, 2007). Aspiring teachers interact with this cognitive model over several sessions spanning several weeks in micro-teaching interactions lasting 10–30 minutes, during which they attempt to negotiate the simulated classroom environment while adapting their teaching to the diversity of students they face.

### *Mobile Simulations as Assessment Platforms*

With the preceding rationales in mind for both mobile technologies and simulations and the specific example of simSchool illustrating that complex cognitive models (e.g., of teaching and learning) can be addressed in a simulation, the unique affordances of mobile simulations come into focus as elements of an alternative assessment platform. The integration of thinking with action in a mobile simulation, for example, has important consequences for performance assessment, with extensions to summative assessment (Clarke-Midura, Code, Dede, Mayrath, & Zap, 2012). Two of the consequences are noteworthy because mobile technologies leverage: (a) embedded tasks-as-performance of knowledge-in-action and (b) unobtrusive observational methods. To elaborate on these consequences, the next section will discuss three roles of mobile technology in digital assessments, the phases of interactive assessment in a mobile environment, and the new analysis environment created by the new affordances.

**Three roles of mobile technology in digital assessments.** As assessment experts have outlined (Donovan, Bransford, & Pellegrino, 1999; Pellegrino, Chudowsky, & Glaser, 2001), all assessments are based on "a model of how students represent knowledge and develop competence in the subject domain, tasks, or situations that allow one to observe students' performance, and an interpretation method for drawing inferences from the performance evidence thus obtained" (Pellegrino et al, 1999, pp. 36). These features of assessment—task environment, data collection, and analysis—are supported in new ways by cloud-based mobile applications, such as simSchool, that have been designed for highly interactive adaptive learning with embedded assessment.

For example, in simSchool, the task environment for the teacher is the planning and control of teaching while facing a diversity of learners. The program collects data automatically as the teacher interacts with the artificial students and makes decisions about what and when to teach as well as whether or not to speak (and if so, how to approach students). Analysis is supported by highly detailed information about the decisions and their impact on a computer model of student learning, and a social environment allows sharing of the successes and failed attempts in the virtual practice environment.

The task environment of a mobile application is normally distributed in the cloud and can involve input from the real world and peers as well as integrate the user and the application interface with the rest of the Internet-based world of knowledge, all while the user is on the go, situated in the real world. From a performance assessment perspective, this allows a mobile application design to include three unique capabilities:

- Combinations of automated and human help in real and asynchronous time, including crowdsourced help databases that are updated in real time as users interact with the system, keyed to the physical location, time, and current experience level of the user
- The display of user knowledge in the form of decisions and actions within the application, with associated time-based trajectories of performance processes as well as results, which can be aggregated in near real time in the cloud and segmented by geographic, time, and other parameters

- Subtle prompts for the user to create natural artifacts that might be simultaneously useful to them in some real or imagined untethered setting while also being of value for unobtrusive assessment observations and analysis

Readers can consult several sources for linkages to performance assessment theory (Black & Wiliam, 1998; Forkosh-Baruch, Gibson, Schulz-Zander, & Webb, 2009; Gibson, 2006); the literature on integration of these new affordances with a theory of digital assessment is still in formation (Gibson, 2010), although several recent contributions are beginning to define its outlines (see (Ifenthaler, Isaias, Spector, Kinshuk, & Sampson, 2011; Mayrath, Clarke-Midura, & Robinson, 2012; Quellmalz, Timms, & Schneider, 2009; Shute & Ke, 2012; Tobias & Fletcher, 2011).

Data collection mechanisms in mobile applications can be designed to work on several time scales and in many dimensions at the same time, in real geographic places as well as hypothetical variable spaces within the applications. Thus, the new era of data collection in education is now characterized by multidimensional, complex, layered evidence of knowledge and performance capabilities (Educational Testing Services, 2012; Ifenthaler, Eseryel, & Ge, 2012). For example, in a social game using mobile devices, participants might be in several locations around the world during simultaneous activities, while later, others can join and replay or build asynchronously on past performances. In addition, with distributed data collection taking place in the cloud, the events per second collected can be dynamically distributed to servers as the user load varies over time. This provides high-resolution, sharable, near-real-time data collection. Because mobile applications can be made aware of both geography and time in high-resolution multidimensional detail, the result is "big data." Tens of thousands of records per assessment event is becoming typical, even for an individual performance lasting only a few minutes. These new game, simulation, and mobile application-based records are a challenge to analyze and compare with the data collection methods of a typical large-scale multiple-choice test and the data records from traditional assessments at the school and individual level (Behrens, Mislevy, Dicerbo, & Levy, 2011; Webb & Gibson, 2011).

Automated help from algorithms integrated with the near-real-time involvement of crowds is a hallmark of mobile technologies designed to provide formative feedback within a learning community. Prior to mobile technologies, expert knowledge was encoded into feedback systems that, with some effort, could be integrated with automated help from algorithms, but the feedback system itself rarely, if ever, evolved. With mobile technologies powered by approaches such as Leverage (http://www.pr-sol.com) that support mobile adaptive applications, now crowd-based knowledge of experts and others allow for a constantly improving feedback system. Constant evolution and adaptability, however, brings with it numerous analysis challenges. In the next section, two aspects of analysis are further discussed: (a) the phases of adaptive assessment, and (b) the dimensions, framework, and tools of analysis

**Phases of adaptive assessment.** An important distinction must first be drawn between an application that adapts to an individual user by choosing from among preplanned pathways of interaction, and a constantly adapting application. Both types might be called "adaptive applications," but the first type is primarily adapting based on existing pathways of interaction, whereas the second type must, in addition, be simultaneously adapting to a larger environment of users (e.g., assessment and research experts, domain specialists, application users, public users of the data). This second kind of adaptability requires the application to find and exploit patterns emerging from the data produced by its user interactions. Independent of this distinction of adapting to individuals and groups is the issue of whether the application then also performs assessment functions and, if so, for whose benefit and using what methods. These issues are discussed in the following section in terms of the purpose, audience, and media implementation options that an assessment designer selects and maximizes. But first, this section outlines the phases of the adaptive process.

An adaptive assessment goes through at least four distinct phases to both personalize the experience and respond to changing conditions, conceptions, and norms in its relevant community. In the Conceptual Assessment Framework (Mislevy, Steinberg, & Almond, 2003) model, adaptation is seen as a delivery issue, and the stages are placed into the context of Evidence-Centered Design (Mislevy, 2011) of simulation-based assessments. The terms preferred here are slightly different, as explained below:

- Prompting performance
- Gathering data
- Making inferences
- Adapting interactions

As developed in Almond, Steinberg, and Mislevy (2002) and Mislevy et al. (2003), four stages include *activity selection, presentation process, evidence identification,* and *evidence accumulation.* However, to support a constantly evolving application—one that is itself learning from the process of interacting with users, as exemplified in the Leverage approach (Gibson & Jakl, 2013)—rather than only "selecting" activities, an adaptive assessment must also adjust activities, create new interactions, include updated contextual information, and adapt its interactions by making changes in the interface, the interaction rules, and the selection and use of digital resources. The presentation process in an assessment prompts the user to perform in some way. Data is then gathered and inferences are made, which involves identifying, accumulating, and using evidence. See Holland, Holyoak, Nisbett, and Thagard (1986) for a broad overview of the processes of induction—inference, learning, and discovery—with applications to machine learning.

**Analysis dimensions, framework, and tools.** Three perspectives on analysis of dynamic performances are supported in unique new ways by mobile technologies,

**Table 1.** Decision and Dilemma Dimensions of Assessment

| Audience | Purpose | Media |
|---|---|---|
| Self | Mirror | Artifacts |
| Advisors | Map | Focus |
| Public | Sonnet | Ownership |

**Table 2.** Analysis Tools for Adaptive Mobile Technology-Based Assessments

| Networks | Ontologies | Data Mining |
|---|---|---|
| Bayesian | Knowledge engineering | Exploratory data analysis |
| Coherence | Semantics | Symbolic regression |
| Neural nets | Semantics | |

including (a) how purpose, audience, and media-related issues intersect; (b) how the Conceptual Assessment Framework (Mislevy et al., 2003) elements of task, student, and evidence models interact; and (c) how an analysis framework that includes networks, ontologies, and data mining becomes distributed with mobile technologies. These three perspectives are critical for the process of adaptation and will be briefly outlined next.

I proposed a series of guiding questions, first introduced in the context of performance-based portfolio systems (Gibson, 2004b), to help assessment system designers. The questions encouraged designers to raise and answer questions about the challenges and dilemmas that arise at the intersection of the audience, purpose, and primary media issues of an assessment system (Table 1). An example of such an intersectional question is: "Who is the primary user of the information of the assessment, and what do they want to know?" The public might want to know if the individual is ready to safely and effectively work in a medical facility, whereas the person's teachers may want to know if there are still gaps in knowledge and skills that need to be addressed, and the individual may be most interested in deciding what strengths are firmly under control in order to define an area for deeper learning.

A second dimension, *purposes*, is divided into three broad areas, following a suggestion by Diez (1996) that a mirror's main purpose is self-reflection, a map's purpose is showing how things fit together in a larger context, and a sonnet's purpose is to express a thought within a form and format acceptable to some community of domain specialists.

The third dimension of the framework raises questions about how issues of audience and purpose change when the means, materials, and ethical issues of assessment evidence are brought to the foreground.

In mobile technology-based assessments, these core questions remain important structural design considerations. However, in addition, due in particular to cloud-based computational power in handheld devices, applications need to switch quickly and effectively for changing audiences, purposes, and material implementations. Failing to do so could imperil the relevancy of the feedback and minimize the effectiveness of the adaptation decisions, with consequences for assessment. Cloud-based approaches to knowledge, data collection, and community are a natural fit with the multidimensional, many-layered negotiations that need to occur as an assessment system fulfills its role within a community.

Within the structure of an assessment system, a core process occurs that translates user actions and artifacts into evidence of what someone knows and can do. The main components of the process are articulated in the Conceptual Assessment Framework (Mislevy et al., 2003), which can be summarized in the following way: The task sets the context for performance and provides performance affordances that are unique to the digital device's interface. Some actions are better supported than others, and these constraints need to be kept in mind when designing and then interpreting a performance. Each student who experiences the planned space of the mobile technology assessment leaves an actual path of performance that can be compared to past performances as well as group and expert performances using the tools and approaches described below. Then, based on the task and the actual path of performance, the assessment process should then identify, classify, and summarize evidence using inference rules that domain experts have shaped using their models of both the domain and how people will perform within the mobile technology application. In an adaptive application, those inference rules are also reshaped and influenced over time as people use the application (Figure 1). This creates an evidence base for analysis, which provides a data set for new tools of analysis that are uniquely suited to mobile technology applications.

Three groups of tools are particularly useful for finding complex patterns in the performance paths of people interacting with mobile simulations: network representations, domain ontologies, and tools and approaches that come under the umbrella of data mining (Table 2). Network representations are a way to visualize as well as analyze the structural and functional relationships inherent in a person's performance paths. A domain ontology connects a path to what is already known about performance in a particular field and its practices, and data mining is a general method of discovering patterns in the data. These tools are enhancements to linear statistics that allow analysts to deal with and better understand complex nonlinear relationships (Gibson & Knezek, 2011) and to seek patterns of even weak signals within the noisy clusters of data from a user's interactions with a mobile application. See Gibson (2013) for more details about the analysis tools.

## Conclusion

Mobile technologies' unique affordances for teaching and assessment, when paired with automated high-resolution data collection methods and analysis engines, can create unique distributed tools for virtual performance assessment. simSchool, a simulation designed for the acquisition of teacher knowledge and skills, provides examples from its field-tested measurement framework for teacher assessment that may be broadly applicable to other kinds of interactive and adaptive educational applications. Cloud-based mobile applications that have been designed for highly interactive adaptive learning with embedded assessments involve new kinds of task environments, data collection methods, analysis tools, and analytic approaches. The key features of the new assessment environment should be included in teacher education and research on teaching and learning in order to best prepare teachers for the dramatically changed computing environment of mobile technologies.

This article presented the following topics with brief rationales and linkages to each other in the hopes of influencing future teacher education courses and curricula: (a) key roles of mobile technologies in digital assessments; (b) how adaptive applications and assessments are organized; and (c) the dimensions, framework, and tools of new approaches to the analysis of big data. If teacher education programs embrace mobile technologies and provide future teachers with opportunities to learn about, use, and be part of related research, they can initiate a practitioner-led movement to advance future teacher assessment policy and practice.


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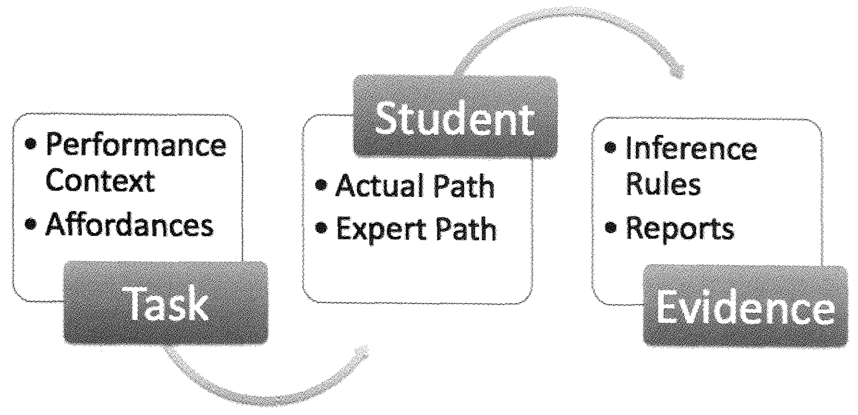


*Figure 1.* Conceptual Assessment Framework.


## Author Notes

*David Gibson is an associate professor of teaching and learning and director of learning engagement at Curtin University in Perth, Australia. He works as a team thought leader, educational researcher, learning scientist, professor, and innovator. With funding from National Science Foundation, U.S. Department of Education, MacArthur Foundation, EDUCAUSE, and others, Gibson's research focuses on complex systems analysis, design and improvement of cyberlearning applications, games and simulations in education, and the use of technology to personalize learning via cognitive modeling, design, and implementation. He is the creator of simSchool (http://www.simschool.org/), a classroom flight simulator for preparing educators, and eFolio (http://www.my-efolio.com/), an online performance-based assessment system. Please address correspondence regarding this article to Dr. David Gibson, Director of Learning Engagement, Curtin University, Bentley, WA 6102, AUS. E-mail: david.c.gibson@curtin.edu.au*


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