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What does it mean for teachers to be data literate: Laying out the skills, knowledge, and dispositions

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ABSTRACT

This article reports on the evolution of a conceptual framework for a construct called data literacy for teachers. Data use has become an emphasis in education but few educators have received sufficient training or preparation pertaining to data literacy skills. This article lays out the framework, identifying the specific knowledge, skills, and dispositions teachers need to use data effectively and responsibly. It concludes with a call to schools of education and teacher preparation programs to begin to integrate data literacy into curricula and practical experiences.

1. Integrating data literacy into teacher preparation

Data use in education has gained increasing importance to make many types of decisions from school improvement to classroom and instructional decision making. Yet, education has struggled to define what it means to be a data literate educator (Mandinach & Gummer, 2011, 2013a, 2016; Schildkamp & Kuiper, 2010). Until recently, the field has paid more attention to assessment literacy (Brookhart, 2011; Christoforidou, Kyriakides, Antoniou, & Creemeers, 2013; Gotch & French, 2014; Kahl, Hofman, & Bryant, 2013; Mandinach, 2014; Plake, 1993) because of the emphasis on assessment results as the most salient form of data for educators. Our work attempts to change the focus to all education data, not just assessment data, to provide a more comprehensive depiction of students. More importantly and also until recently, the field has lacked a common and explicit definition for data literacy. Some researchers have defined a limited number of global skills (Means, Chen, DeBarger, & Padilla, 2011). Some professional development providers have mentioned data literacy as a key competency, but never really defined the construct (Love, Stiles, Mundry, & DiRanna, 2008). Others have posited variations on definitions (Data Quality Campaign, 2014; North Carolina Department of Public Instruction, 2013). The Data Quality Campaign's definition, developed by a group of experts from diverse stakeholder groups, is meant to be generic, communicating the basic ideas to various stakeholder groups that include policymakers, professional organizations, and the general public.

> Data-literate educators continuously, effectively, and ethically access, interpret, act on, and communicate multiple types of data from state, local, classroom, and other sources to improve outcomes for students in a manner appropriate to educators' professional roles and responsibilities. (p. 1)

The North Carolina Department of Public Instruction is the only state in the United States that has deemed data use sufficiently important to develop a webpage on which they lay out to educators the meaning of data literacy. Data literacy is defined as "one's level of understanding of how to find, evaluate, and use data to inform instruction" (p. 1). The definition is meant to convey in the simplest terms what data literacy is for the purpose of informing educators and preparing them to use data. Other states such as Virginia strongly promote data skills but have not defined what they mean by data literacy.

These definitions are very general. They do not dive deeply into what data literacy entails in terms of the cognitive skills and knowledge needed to be data literate. To fill that gap and address the need, we (Gummer & Mandinach, 2015; Mandinach & Gummer, 2016) have laid out a definition and identified the skills, knowledge,

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and dispositions that comprise the construct, data literacy for teachers (DLFT).

> Data literacy for teaching is the ability to transform information into actionable instructional knowledge and practices by collecting, analyzing, and interpreting all types of data (assessment, school climate, behavioral, snapshot, longitudinal, moment-to-moment, etc.) to help determine instructional steps. It combines an understanding of data with standards, disciplinary knowledge and practices, curricular knowledge, pedagogical content knowledge, and an understanding of how children learn.

Generic definitions, even when carefully crafted in reference to a sub-group of educators, teachers, do not provide much support in determining why, when, and how to integrate data literacy into an already packed teacher preparation agenda. We first articulate the policy agenda behind the growing emphasis on data literacy. We review relevant research. We then layout the conceptual framework for data literacy for teachers, describing the skills, knowledge, and dispositions we have identified from our work. We conclude with a discussion of the implications for practice and how the work can impact teacher preparation.

Our work is grounded on three propositions that have emerged from our six years of studying data literacy. First, there is no question that educators must be armed with data. Policymakers internationally are emphasizing the need for education to become evidence-based. That means using data from which to make decisions and inform practice. Second, there is a problematic conflation between assessment literacy and data literacy. It has become a major issue impacting the comprehensive adoption of data literacy in education; that is, people think that data are only about assessments, and this is far from the case (Mandinach & Gummer, 2016; Mandinach, Kahl, Parton, & Carson, 2014).

Third and most relevant to teacher preparation around use data, our findings have indicated that simply relying on professional development to enhance teachers' data literacy is inadequate (Mandinach & Gummer, 2012, 2013a, 2013b, 2016). As will be described below as we lay out the conceptual framework for DLFT, data skills (what we call data use for teaching which is a component to the overarching construct, DLFT) must be combined with other sources of knowledge, in particular content knowledge and pedagogical content knowledge (Shulman, 1986, 1987). The data skills must be triangulated with such knowledge. However, professional development providers often lack in-depth knowledge of content and pedagogy to enable such triangulation. In fact, some professional development providers admit that their models do not extend to the transformation of information into instructional decisions (Mandinach & Gummer, 2012, 2013b, 2016). Furthermore, introducing data use to educators after they are already in practice may be too late. Many believe that early introductions are preferred (Mandinach & Gummer, 2012). Thus, it is our belief based on our prior work, that teacher preparation programs must begin to introduce data use to teacher candidates, with professional development further enhancing the skills. Teacher preparation programs are uniquely situated to provide the triangulation of data skills with the other essential forms of knowledge that Shulman (1986, 1987) has described.

1.1. Positioning data use in policy and research

1.1.1. Policy and policymakers

Data-driven decision making has risen to a level of importance in education in many countries as evidenced by the emerging amount of research on this topic. While Schildkamp, Lai, and Earl (2013) have noted barriers and enablers to the enculturation of data in at least five European countries, research is beginning to emerge, reflecting the growing importance of data use globally (Schildkamp & Lai, 2013; Schildkamp et al., 2013). Focusing specifically on data literacy, this research indicated that much needs to be done in terms of building educators' capacity to use data in their practice. Although two countries (the United Kingdom and Poland) reported having data skills, whereas Germany, Lithuania, and the Netherlands were found to lack data knowledge and skills, none of the countries showed evidence of deep data literacy, comprehensive professional development around data use, or training to prepare educators to use data. It would be interesting to see if policies exist that address data literacy in educator training or if such policies are viable.

Much attention from policymakers in the United States has been given to the importance of teachers using data. Former Secretary of Education Arne Duncan (2009a, 2009b, 2009c, 2010a, 2010b, 2012) has spoken widely about the need for teachers to use data and the importance of such evidence-driven practice. In fact, at a national conference sponsored by the Data Quality Campaign, Duncan (2012) publically challenged schools of education to focus on and accelerate efforts to educate educators to use data. Further, data use is one of the four pillars in the American Recovery and Reinvestment Act (ARRA, 2009) and in the Race to the Top (U.S. Department of Education, 2009), two major initiatives from the U. S. Department of Education.

Professional organizations such as the Council for Accreditation of Educator Preparation (CAEP) and the Council of Chief State School Officers (CCSSO) have included the capacity to use data among their recommendations and standards. The National Board of Professional Teaching Standards also has advocated for teachers' data literacy (Aguerrebere, 2009; Thorpe, 2014). A Blue Ribbon Panel (2010) report released by NCATE, CAEP's predecessor, and endorsed by Duncan (2010b) recommended that teacher candidates know how to make data-driven decisions. It further recommended that teacher candidates must be able to analyze student learning needs and make instructional adjustments by using student performance data and other sources of data to inform their practice. CAEP has made concrete efforts to take action with teacher preparation programs to increase their awareness about the need for educators to become data literacy (Breaux & Chepko, 2015; Mandinach & Gummer, 2015).

CCSSO (2013, 2015) released the InTASC (Interstate New Teacher Assessment and Support Consortium) standards for teaching that articulated 10 standards infused with data literacy, each standard identifying various forms of knowledge, dispositions, and performance skills that are required of teachers. The identification of "using data to support learning" as one of the InTASC cross-cutting themes emphasizes the importance of data literacy. The document further specifies aspects of the data theme that are related to nine of the knowledge elements, nine dispositions elements, and 20 performance elements across the 10 standards. For example, Standard 9h (Professional Learning and Ethical Practice; Essential Knowledge) is, "The teacher knows how to use learner data to analyze practice and differentiate instruction accordingly" (CCSSO, 2013, p. 41). Standard 10b (Leadership and Collaboration; Performances) is, "The teacher works with other school professionals to plan and jointly facilitate learning on how to meet diverse needs of learners" (p. 45). When we did a crosswalk across the standards, we identified 66 data literacy elements. It is clear that the components of data literacy are well represented in the InTASC standards (CCSSO, 2013).

CCSSO (2012) also released a major policy document, *Our Responsibility, Our Promise: Transforming Educator Preparation and Entry into the Profession*. The document refers to the need for

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teachers to be assessment literate, although what is outlined is actually data literacy. This issue speaks to the conflation of assessment and data literacy, a major issue plaguing the comprehensive adoption of data literacy in education; that is, people think that data are only about assessments, and this is far from the case (Mandinach & Gummer, 2016; Mandinach et al., 2015).

The Data Quality Campaign, a bipartisan advocacy organization, has been a strong proponent of improving data literacy among educators. They have provided multiple supports and activities including:

- A paper, *Empowering Teachers with Data*: *Policies and Practices to Promote Educator Data Literacy* (Data Quality Campaign, 2014a).
- A national event to promote and increase awareness about data literacy was held (Data Quality Campaign, 2014b).
- A webinar to debate the differences between data literacy and assessment literacy (Data Quality Campaign, 2014c).

In summary, policymakers are clearly emphasizing the importance of data use. They are putting into place some of the requirements necessary for the effective use of data. The key will be to translate the policy recommendations into actual practice, effecting change where needed to make data use a more accepted and fully integrated practice at all levels of the educational system.

1.1.2. Research

In some ways, policymakers are further along in their thinking about data literacy among educators than are researchers. Work in the area of data-driven decision making has focused on teachers in a number of ways, but has rarely addressed teacher preparation. Many articles and studies have noted the importance for teachers to know how to use data effectively to inform their practice and the need to build educators' capacity to use data (Baker, 2003; Choppin, 2002; Feldman & Tung, 2001; Hamilton et al., 2009; Ikemoto & Marsh, 2007; Mandinach & Honey, 2008; Mason, 2002; Mandinach, 2009, 2012; Miller, 2009). There have been numerous calls for high-quality and sustained professional development to facilitate data literacy (Baker, 2003; Mandinach, Rivas, Light, & Heinze, 2006; Means, Padilla, & Gallagher, 2010; Schafer & Lissitz, 1987; Wise, Lukin, & Roos, 1991). Other articles in this special issue highlight the impact of professional development on data use in classroom processes and student achievement (Lai & McNaughton, this issue; Poortman & Schildkamp, this issue). Yet the current practice of preparing educators to use data only goes so far. Though having good professional development is important, there also is a pressing need for the infrastructure to support the infusion of data use into schools and districts (Marsh, Pane, & Hamilton, 2006) and in teacher preparation programs (Duncan, 2012; Mandinach & Gummer, 2013b, 2016).

While the existing literature focuses on the practicing cohort of teachers with an emphasis on in-service training, and professional development, little attention had been devoted to teacher preparation and data literacy in pre-service programs. Recognizing the dearth of knowledge about the role of teacher preparation in developing data literacy, early in 2011, we convened a meeting of key stakeholders to discuss what schools of education can do to prepare educators to use data. The outcome of that meeting was a call to action (Mandinach & Gummer, 2011) that appeared in the *Educational Researcher* (Mandinach & Gummer, 2013b). The paper reported on the varying perspectives of different stakeholder groups, as well as a clear indication of many of the challenges. It outlined a research agenda needed to inform the field, including a comprehensive survey to schools of education to better understand the landscape of course offerings. The journal article laid out the systemic nature of the problem and took the perspective that professional development providers can only go so far as to train some of the current cohort of teachers. It was clear that something must be done to improve the pipeline of educators, looking to schools of education to respond by integrating data use into their course offerings to address the need at the pre-service level.

The 2011 meeting became the impetus for a line of research that we describe below. It has included the theoretical work to develop a conceptual framework for the construct, DLFT (Gummer & Mandinach, 2015). It has also included empirical work to examine the landscape of what schools of education are doing to build educators' data literacy (Mandinach & Friedman, 2015; Mandinach, Friedman, & Gummer, 2015).

2. Conceptual framework for data literacy for teachers

2.1. Evolution of the framework

Our first effort to understand data literacy involved convening 55 experts to determine how they defined the construct (Mandinach & Gummer, 2012, 2013a). We first examined how published materials, resources, and books dealt with data literacy. Second, we required each expert to provide a definition of data literacy. Third, we asked them to differentiate between data literacy and assessment literacy.

The review of the professional materials indicated that the texts focused on inquiry cycles, different types of data, and the role of data analysis to inform decisions. The texts, however, failed to make clear what data literacy is, or what the specific skills involved in data use are. The experts clearly indicated that data literacy was a more comprehensive construct than assessment literacy with the latter subsumed as part of the former. From the text analyses, expert definitions, and analyses of the transcripts from the convening, we extracted over 100 sets of knowledge and skills. Through further analysis of the transcripts and the experts' definitions, the knowledge and skills were sorted into the following categories: inquiry process, habits of mind, data quality, data properties, data use procedural skills, transformation of data to information, and transformation of information to implementation.

In a subsequent project, we conducted an analysis of state licensure documents to understand how data literacy skills were described, if at all (Mandinach, Parton, Gummer, & Anderson, 2015a). The purpose of this activity was to understand what states require of teachers for them to gain licensure. The underlying assumption was that if standards for teacher licensing included requirements for data literacy, teacher preparation programs would need to align themselves to the regulations. Our examination yielded interesting yet unsurprising findings. Assessment literacy was a more prevalent skill required by states than data literacy. However, some states articulated the knowledge and skills that pertain to data literacy as part of their requirements. Some states (Kansas, Kentucky, North Carolina, Ohio, South Dakota, Tennessee) even had an explicit data competency and a developmental continuum from novice to expert for data use. For other states, there was a real dearth of data skills required. There was a vast range from 0 to 59 data-related skills. At the extremes, one state made no mention of any data skills. At the other extreme, a state included 59 skills such as collect data, manage data, examine data, access data, adjust instruction, differentiate instruction, use data ethically, involve stakeholders, communicate about data, and verify results.

A message that emerged following our analyses of the data from the meeting with the experts and our review of licensure requirements is that for teachers, data literacy must be integrated with other essential aspects of teaching, namely knowledge of content domain and pedagogical content knowledge (Shulman, 1986, 1987). For teachers to use data effectively, data must be

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contextualized within the content domain and its learning progressions. Once teachers understand what the data mean in reference to the goals and learning objectives of the content domains, they then must determine what instructional steps to take. This means that they must invoke their pedagogical content knowledge. We therefore conceptualized an interaction among three components, content knowledge, pedagogical content knowledge, and data use for teaching (what we termed the knowledge and skills around data use). After a culling process, the remaining and synthesized 59 specific skills from the two studies were categorized into six components (Gummer & Mandinach, 2015). In Gummer and Mandinach (2015), the first two components, *Identify Problems* and *Frame Questions*, were separate. No specific skills could be identified that fell under *Frame Questions* and this fact did not support a separate component. They then were combined because distinctions could not easily be made (Mandinach & Gummer, 2016). The remaining components now include: *Identify Problems and Frame Questions*, *Use Data*, *Transform Data into Information*, *Transform Information into Decisions,* and *Evaluate Outcomes*.

2.2. What DLFT looks like now

The framework that included only the three domains described above seemed like a straightforward and simplistic way of depicting the different kinds of knowledge and skills teachers use in their practice. Yet, we recognized that the original framework lacked reference to some of the forms of knowledge Shulman (1987) described as essential to good teaching and widely accepted theoretically in the field of education. The conceptual framework (Mandinach & Gummer, 2016) therefore was elaborated to include the full scope of Shulman's (1987) foundational knowledge. We have now included seven key knowledge areas that integrate with data use in the inquiry process: content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge; knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational ends, purposes and values. These areas provide essential information and feed into the data use for teaching domain of the DLFT construct. The data use for teaching domain is then comprised of five components under which we have associated specific knowledge and skills. The domains include: *identify problems and frame questions*, *use data*, *transform data into information*, *transform information into a decision*, and *evaluate outcomes*. The specific skills and knowledge are explained below. The conceptual framework is presented in Fig. 1.[1]

We now unpack the specific skills and knowledge that have been identified and categorized across the five components. It is important for us to recognize other relevant conceptual work that has been conducted and informed our thinking (Coburn & Turner, 2011; Lai & Schildkamp, 2013; Mandinach, Honey, Light, & Brunner, 2008; Marsh, 2012; Means et al., 2010, 2011; Schildkamp & Poortman, 2015; SLDS State Support Team, 2015). There is overlap with these research efforts, yet what may distinguish our work is the explicit laying out of the skills and knowledge that comprise *Data Use for Teaching*, the component of the DLFT construct that focuses on the data skills, knowledge, and dispositions. The components form a complex and iterative cycle of inquiry culled from an examination of the other frameworks, the experts' definitions of data literacy, and the examination of state licensure and certification documents. We recognize that some of the knowledge and skills sub-components and elements could be placed in different components. We also recognize that there may be some degree of overlap. This speaks to the complexity of the domain and the iterative nature of using data across the components. It also speaks to the interrelatedness of the skills. There is an explicit logical progression from identifying a problem of practice to evaluating the outcomes of a decision. However, it is essential to be mindful of the iterative nature of the process. Most decision-making processes are not linear or even finite. They require reflection and recasting of investigation, whether additional data need to be collected, other iterations through the cycle made, further analyses made, new instructional steps identified, or other skills invoked.

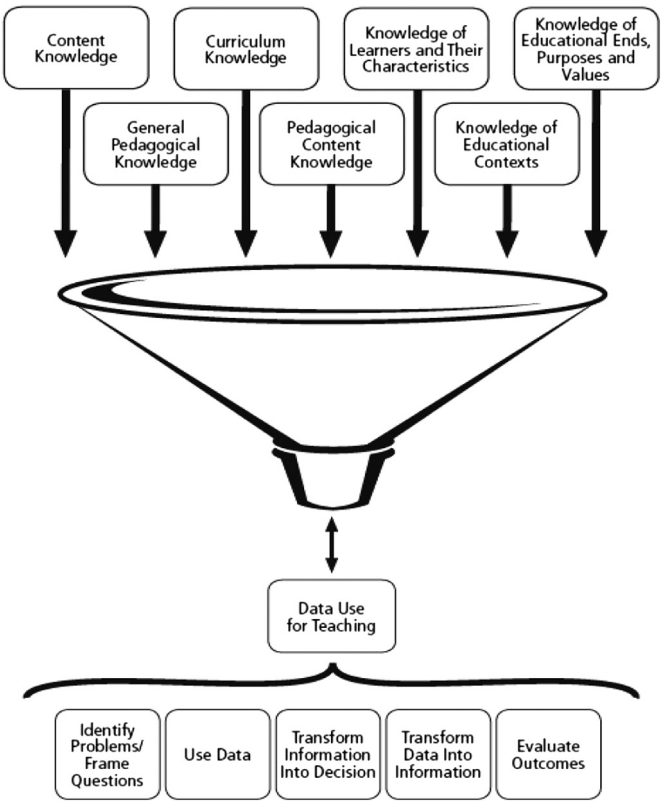

Fig. 1. Conceptual framework for DLFT.

2.2.1. Identify problems and frame questions

As noted above, an earlier version of the conceptual framework (Gummer & Mandinach, 2015) separated these two components, *Identify Problems* and *Frame Questions*. The two skills were collapsed because the licensure documents review failed to differentiate them. The underlying knowledge and skills initiate the iterative inquiry process. Teachers should be able to:

- *Articulate a problem of practice* about a student, group of students, a topical area, the curriculum, or an aspect of instruction. They should be able to identify the problem and explain the issue or question.
- *Understand the context* at the student level to understand the problem with a student or a group of students. Contextualize the learning, behavioral, or motivation issues students may be having will help them to better understand the situation, concretizing the problem that can lead to a decision and subsequent action.

[1] Note the bidirectional arrows to and from *Data Skills for Teaching* which are intended to reflect that the data skills are both influenced by and influence Shulman's seven forms of knowledge.

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- *Understand the context at the school level*. This is a different level of aggregation from student level context. Understand the larger context of a school in which teachers' practice is embedded provides a broad view toward seeking solutions to problems of practice.
- *Involve other participants or stakeholders*, including students. Other educators, parents, and students can provide valuable insights into students' performance. Consultation with them is an important part of the decision-making process.
- *Understand student privacy*. It is increasingly important for teachers to understand the regulations around the protection of student privacy and confidentiality. Data breaches have been increasing at alarming rates and education is not immune. This skill set includes knowing how to discuss data and with whom, understanding data sharing, among other topics.

2.2.2. Use data

The largest component in the inquiry cycle is *Use Data*. This component pertains to the fundamental knowledge and skills that most directly relate to actual data use. We have struggled for terminology here, trying to find wording that is more precise but is sufficiently comprehensive to describe the many skills in this component. For now, we use the terminology, *Use Data*, recognizing it is not sufficiently descriptive. We have identified 27 skills under the *Use Data* component.

- *Identify possible sources of data*. Teachers must be able to evaluate the right data for the particular problem of interest, data that are aligned at the problem of practice and actionable.
- *Understand the purposes of different data sources*. Teachers must understand the purpose of different data because different data have different uses and utility.
- *Understand how to generate data*. Generating data is important because not all data are already produced. Teachers generate a plethora of data every day, ranging from moment to moment assessments of students to more long-term determinations of students' understanding.
- *Understand assessment*. Teachers need to understand what makes a sound assessment. They must understand the different kinds of assessments, their purposes, and their uses.
- *Use formative and summative assessments*. Teachers must know how to use both formative and summative assessments, including understanding when which sources of data are appropriate for instructional versus assessment/grading decision making is a key skill for teachers. These sources of data yield different kinds of information that may be more or less aligned to instructional practice.
- *Develop sound assessment design and implementation*. Teachers must be able to develop assessments whether by hand or through the use of assessment systems. This set of knowledge and skills entails knowing how to design items and combine them into a meaningful test that yields reliable and valid data.
- *Understand data properties*. Data have characteristics and qualities that teachers need to understand and have alignment with the purposes of data use. Data have different levels (e.g., total score, composite, strand, item-level) and these levels may be more appropriate for different questions.
- *Use multiple measures/sources of data*. This is a foundational concept in data-driven decision making and educational measurement; that is, it is important not to rely on just one measure but to triangulate among multiple sources of data to obtain a better and more accurate depiction of the situation.
- *Use qualitative and quantitative data*. Most educators think of data as numbers that can be quantified. Data are much more. It is important to recognize that not all data are quantitative and that qualitative indices can be valued and informative sources.
- *Understand specificity of data to question/problem*. This set refers to the knowledge and skills teachers must have to understand that some data can address the issue being examined, while other data will not.
- *Understand what data are appropriate*. Teachers must be able to understand that not all data are appropriate or applicable for every given circumstance. It is important to recognize when specific data are or are not relevant for the problem at hand.
- *Understand data quality*. Data quality has many aspects such as validity, timeliness, and consistency of the data. Foundational to data use is knowing that the data being used are "clean", timely in terms of from data collection to use, and valid for the purposes of use and interpretation. Data must not be misleading or out of range; that is, if the highest score possible is 100 and a score is entered as 110, teachers must recognize that there is a problem.
- *Understand elements of data accuracy, appropriateness, and completeness*. This is a subskill from the more general one about data quality. Data must be accurate. They also must be appropriate to the problem of practice or the question being addressed and as complete as possible. Using data that lack any of these qualities can invalidate the conclusions drawn from the data collection and analysis process.
- *Understand how to access data*. Teachers must know how data are stored and made available. They must be able to navigate across multiple data systems. Increasingly, educational data are stored in electronic formats for easy and safe access and analysis. Note that accessing data is different from generating data. The former entails data retrieval. The latter entails the actual creation of data.
- *Find, locate, access, and retrieve data*. Teachers must have the ability to locate the data needed to address a problem of practice or educational question and be able to pull out those data for subsequent examination.
- *Use technologies to support data use*. Teachers must know how to use technologies to support data use through data warehouses, assessment systems, student information systems, instructional management systems, data dashboards, simple spreadsheets, apps, and other relevant technologies that provide access to, analysis, and reporting of data.
- *Understand how to analyze data*. Teachers must understand what the data mean. Analyzing data enables the user to understand what the data mean, whether qualitative or quantitative. Analysis is one of the most foundational skills in data literacy.
- *Understand statistics and psychometrics*. Teachers need not be expert statisticians or psychometricans, but they must have a fundamental knowledge of both topics. By statistics we mean simple statistics such as central tendency and dispersion, not more advanced techniques like regression or ANOVA. By psychometrics, we mean understanding topics such as reliability, validity, and error of measurement.
- *Manage data*. Teachers must know how to manage data because there is such a multitude of data, that the wealth of data must be handled with accuracy, coded, stored, and arranged in a coherent manner for latter access and examination.
- *Organize data* into a meaningful and manageable representation of the information.
- *Prioritize data* because not all data are as relevant or as important as others. It is therefore important to arrange the data according to the utility of the issue being addressed.
- *Examine data. Data examination* means to scrutinize or inspect them in a meaningful way to address a particular question, hypothesis, or issue.

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- *Integrate data* by examining, analyzing, and combining them in some meaningful way for sense making.
- *Manipulate data*. Data manipulation entails handling or treating the data as part of the examination process.
- *Drill down into data*. Total test scores do not tell the complete story. Teachers need to drill down to strand or item levels to really understand misconceptions and understandings.
- *Aggregate data*. Teachers must understand that there are times when looking to whole group data is important.
- *Disaggregate data*. Teachers must understand the need to examine subgroup differences. They must know how to break down data into subgroups to discern differences across group performance.

2.2.3. Transform data into information

The transformation of data to information is essentially about moving data toward information on which actions can be taken. Teachers use the context of the classroom and about students to make meaning and inform decisions. Nine skills were identified.

- *Consider the impact and consequences* because the outcome of the inquiry process and decision is an impact on the circumstances that has consequences which can be either expected or unexpected.
- *Generate hypothetical connections to instruction*. Teachers must foresee how what they plan to do instructionally fits into the flow of students' learning and progress. To do this, they must know how to project hypothetically, what will happen if they take various courses of action. This is based on hypotheses or educated guesses about why things are happening the way they are and what might happen with different instructional steps.
- *Test assumptions* early in the inquiry cycle to help determine if teachers are on the right track or off target.
- *Understand how to interpret data*. Teachers must know what the data mean. Interpretation gives meaning to the data and provides explanations.
- *Understand and use data displays and representations*. Teachers need to know how to use data displays because data are often graphically depicted, in chart, tables, graphs, and other displays.
- *Assess patterns and trends*. Teachers must be able to discern patterns and trends from data, especially when displays in charts and graphs.
- *Probe for causality*, as an attempt to understand why the behavior, performance, or situation has happened.
- *Use statistics*. Teachers must be able to use simple statistics such as central tendency and dispersion to understand student performance.
- *Synthesize diverse data*. Teachers must know how to synthesize diverse data because often times, disparate data are applied to a problem and must be pulled together in a coherent manner in order for them to make sense.
- *Articulate inferences and conclusions* from the information analyzed during the inquiry process.
- *Summarize and explain data* to pull together an explanation of what the data and information mean.

2.2.4. Transform information into a decision

The next phase of the inquiry process is to transform information into a decision. For teachers, the sets of knowledge and skills focus around the instructional steps that should be taken based on the inquiry cycle. Five skills were identified.

- *Determine next instructional steps*. Based on the evidence that teachers have acquired, they must use those data to plan and determine what are the next logical steps to take instructionally.
- *Monitor student performance*. Teachers need to be able to watch student performance over time to determine if differences have occurred or changed behavior.
- *Diagnose what students need*. Teachers must know how to determine students' learning strengths and weakness from performance over time.
- *Make instructional adjustments*. Teachers must know how to make instructional adjustments based on data they have at hand. This means knowing what instructional actions are appropriate given the information gained from examining data.
- *Understand the context for the decision*. Teachers must understand the setting into which their decision is being fit. This includes knowing about the content, the curriculum, the scope and sequence, and other classroom contextual information.

2.2.5. Evaluate outcomes

The final component in the conceptual framework pertains to examining the impact of the decision making process. Teachers must be able to evaluate the outcomes that result from the decision and recognize that it is an iterative cycle of inquiry. Five skills were identified.

- *Re-examine the original question or problem*. Teachers must recognize the need to look back at the original problem or question to determine if the data and decision have addressed the original issue and what steps need to occur informed by that re-evaluation.
- *Compare performance pre- and post-decision*. Part of the inquiry process is checking to see if there has been a change from before a decision was made and action taken to afterwards. This is to determine the impact of that decision making process.
- *Monitor changes in classroom practices*. Part of evaluating the outcomes is observing what has happened in the classroom based on the actions taken from the decision. Teachers must continue to be aware of the changes to determine if they have been in the desired direction.
- *Monitor student changes in performance*. Teachers must observe changes in their students following a decision to determine if the decision and ensuing intervention has had the desired effect.
- *Consider the need for iterative decision cycles*. Fundamental to the decision making process is the notion of iterative cycles of inquiry. This means that decisions do not have an end point. Data are collected, analyzed, interpreted, and acted upon. Then the cycle begins anew. Teachers must recognize the iterative nature of the teaching and learning process.

2.2.6. Dispositions, habits of mind, or factors that influence data use

There is another category of components that are needed for effective data use, what we are calling dispositions or habits of mind. We chose not to include them in the conceptual framework, but they are important nonetheless. We see these dispositions as general to effective teaching, rather than specific to data use. They are likely to influence data literacy, but are seen as more general habits of mind of good teaching. Substantial research has been conducted in this area and reflects an international perspective (Datnow, Park, & Kennedy-Lewis, 2012; Jimerson, 2013; Kerr, Marsh, Ikemoto, Darilek, & Barney, 2006; Schildkamp et al., 2013; Schildkamp & Kuiper, 2010; Schildkamp & Teddlie, 2008; Vanhoof, Verhaeghe, Van Petegem, & Valcke, 2012). These components are dispositions, beliefs, and habits of mind around data use that

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influence how teachers approach the use of data. We are calling them dispositions as we agree with InTASC (2013) that these are more than just beliefs as they strongly structure what actions teachers undertake. Six dispositions were identified:

- *Belief that all students can learn*. Teachers must believe that all students have the capacity to learn and what actions they take can have a positive effect on student performance.
- *Belief in data/think critically*. Teachers need to believe in the use of data, that data can help them do their jobs more effectively and to think deeply about the problem at hand while using the inquiry cycle to use data to inform a decision.
- *Belief that improvement in education requires a continuous inquiry cycle*. Improvement is a continuous cycle of tweaking things to see if they work, observing outcomes, and making modifications as needed. Teachers need to understand that their work is not a linear, cause-and-effect process, but a cyclical and ongoing process.
- *Ethical use of data, including the protection of privacy and confidentiality of data*. Of the utmost importance is the knowledge about how to protect student data in terms of privacy and confidentiality. This skill is increasingly important now that technological applications are making data use more efficient but also somewhat riskier in terms of data security. Teachers must understand the fundamental ways to use data securely and responsibly.
- *Collaboration* (*vertically and horizontally*). Collaboration is considered an important and valued component in the inquiry process where educators work together to examine data and seek solutions to a particular problem.
- *Communication skills with multiple audiences*. Teachers must be able to discuss results and performance with various audiences, using empirical evidence in the discussion. Audiences include students, parents, guardians, other educators, and other relevant stakeholders. They must be able to adapt their communication to the particular audience.

3. Implications: a systemic perspective on change

It is clear from our analyses that defining DLFT and its component skills is a complex and challenging process. Many skills were identified through our analyses of state licensure documents (Mandinach et al., 2015), and by the experts we convened for our brainstorming conference (Mandinach & Gummer, 2012). Further analyses and deep conceptual thought have occurred since those events.

This section presents looming questions and next steps that can be extrapolated from our work. It is not our intent to overstep findings from our and others' research. That said, we use strong statements to emphasize the necessity of action. These are recommendations intended to serve as a call for action.

3.1. The timing of introducing data literacy

We now believe that the earlier in teachers' careers, the better for the introduction of data-driven decision making. Waiting until teachers are practicing to instill a focus on data or evidence in teaching is too late. Teachers should exit their preparation programs with at least a strong awareness of all of tools of the trade, including how to use data. Teachers' practices will be continually refined and expanded during teaching, but teachers should have experiences with the knowledge and skills of data use while in their pre-service programs. Teachers then can master those sets of knowledge and skills during their work in classrooms and have them reinforced through subsequent professional development.

A related issue is how best to introduce data-driven decision making to teacher candidates. We originally assumed that stand-alone courses were the answer. From our work, we recommend an integrated approach of data into pre-service preparation courses, especially because of the integration of Shulman's (1987) seven areas of teacher knowledge. Teachers may understand the data skills and be able use their knowledge to identify what the students know and do not know in the content domain that they are teaching, but they must then be able to determine what are the best instructional steps to take; that is, they must use their pedagogical content knowledge. It is our opinion that integration has the best chance of providing the triangulated approach. This is not to say that stand-alone courses have no place in teacher preparation.

3.2. How to integrate data literacy

To explain further about why we advocate for the integrated approach to teaching data literacy, we refer back to the conceptual framework depicted in Fig. 1. Our original consideration of only two of the Shulman (1987) areas of teacher knowledge comes from one author's (Gummer's) focus in assessment practices of teachers of science and mathematics (Gummer & Champagne, 2004; Gummer & Shepardson, 2001a, 2001b; Gummer, Cohen, Gates, & Fantz, 2010). The key components of assessment practices for teachers is a strong knowledge of the content area so that they can elicit and recognize the ways in which students demonstrate their understanding of what is being taught. In order to be able to engage the students in formative assessment practices, those that focus on not only identifying where students are in their learning – but also on what students need to experience to improve their understanding, teachers need to know how to connect their sophisticated understanding of the content with the representations of the content in teaching materials – *pedagogical content knowledge*. But this is a simplistic way to consider how data inform teaching at multiple levels.

At the heart of both formative assessment and data literacy for teachers is the *teacher knowledge and skills of learners and their characteristics*. Without an understanding informed by the learning sciences of how students think and act, the teacher is at a disadvantage in determining how to structure learning experience. While much of this knowledge and skill area might also be associated with pedagogical content knowledge, there is a much richer set of data that can inform a teacher's knowledge of learners and their characteristics. These data include demographic, behavior, and attendance data. Understanding the ways in which to use these data to support the pre-service teacher to best inform classroom practices could start in early foundation courses in a teacher education program. Faculty in an education philosophy course could incorporate historical and current demographic data to support the rationale for different education programs over time. Rather than just focusing on the findings from studies in introductory educational psychology courses for teachers, faculty might provide data sets and provide pre-service teachers with the opportunity to interpret the data and draw inferences. Such courses might also include exercises that focus pre-service teachers on interpretations of attendance or behavioral data in scenarios that address key themes that are typically addressed in such courses. Data that pre-service teachers might address could also include teacher comments and student self-reflections to provide a broader perspective of what counts as data.

Knowledge of educational contexts is key to understanding how to act. Data at the school and district level can be incorporated into educational foundation courses to help pre-service teachers with experiences of what they will encounter when they start to teach. Such courses might provide opportunities for students to delve into

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data sites such as individual school and district report cards to help them characterize the educational settings that surround them. They might also engage in experiences with aggregated state data sets that are available at the state level, such as *EdWise* currently being developed by the Kauffman Foundation (2015) so that they can situate their developing understanding of the schools and districts with which they work locally.

Knowledge of education ends, purposes, and values is key to understanding from where the current focus on educational standards and tests has emerged. The data in the standards is not numerical, but the statements of what students need to know and be able to do that make up the Common Core State Standards in English Language Arts and Mathematics (Common Core State Standards Initiative, 2010; 2015) and the Next Generation Science Standards (NGSS Lead States, 2013) are at the heart of how teachers use data in the classroom to determine how well students are attaining educational goals and objectives. Without the roadmaps that are illuminated by the standards, teachers' use of diagnostic and monitoring data are disconnected from instructional decision making.

We strongly considered leaving out general pedagogical knowledge and curriculum knowledge from our framework. Yet we asked ourselves how a teacher could use data to inform instruction without knowledge what curriculum is being used and how that curriculum relates to others. In addition, the DLFT inquiry cycle is focused on teaching, and the latter half of the inquiry cycle is heavily weighted on instructional decision making. Without a focus on the decisions of data-driven decision making, teacher data use happens in a vacuum. However, one of our considerations is that much of the professional development literature on teacher data use training focuses on general pedagogical strategies that make suggestions of alternative experiences for students not well connected to the content that students are to learn. Building experiences for pre-service teachers in pedagogy and methods courses that provide examples of multiple forms of data use are easy to consider. As students are learning about the principles of curriculum development, they should also be learning about implementation and the data they generate in such exercises provide another opportunity to develop data literacy.

In part, where we have emerged on these two issues reflects why schools of education and teacher preparation programs have a unique role in developing the capacity among teachers to use data effectively. Professional development providers on data use typically do not address the *Transformation of Information into a Decision* component, although some do (e.g., the Learning Schools Model in New Zealand). That is, their training does not provide guidance on what to do instructionally. In addition, by the time teachers are practicing, many of their skills are less malleable than when they were learning about methods and instruction. Schools of education have faculty that prepare teachers to teach specific content disciplines. Therefore, we strongly support the notion of the integration of data-driven decision making into teacher preparation programs early and across the curriculum.

3.3. A systemic approach

We have written elsewhere (Mandinach & Gummer, 2013b, 2016) about change in teacher preparation programs coming slowly and requiring a systemic approach. We will summarize here some of the major players in the United States that are needed to facilitate systemic change. We recognize that the system components in other countries might differ, and we invite an international comparison that facilitates better understanding of the key drivers and barriers to improving data literacy for teachers. Cross-country comparisons of enablers and barriers such as those conducted by Schildkamp et al. (2013) could be extended to consider the policy and organizational components that systemically might impact the development of data literate teaching corps internationally. For the purposes here, we examine those components within the context of the United States.

Schools of education are the central and the major player in the system. Because of the emerging policies and accountability requirements, they must be responsive to the policy changes (U.S. Department of Education, 2014; White House, 2014) that have been announced to improve teacher preparation programs. They will undergo scrutiny from accountability measures that evaluate the institution and their graduates. They must address the requirements that are outlined in state licensure and certification requirements. They strive to be responsive to the needs of local school districts where their graduates are placed. Their graduates must be able to pass licensure tests that enable them to practice in particular states. Data literacy is only one of many topics that now must be addressed as teacher preparation programs are reconsidered and restructured for continuous improvement.

State education agencies and their licensure components play a major role in the system. They design the regulations and requirements around the skills and knowledge teachers are required to have, and therefore what schools of education are required to provide to teacher candidates. Our analyses have shown that states vary substantially in how they treat data skills and knowledge, ranging from nothing to over 50 separate and defined skills (Mandinach et al., 2015). Some states even have a specific data competency. However, more states focus on assessment literacy than data literacy. The extent to which schools of education actually pay attention to and design their curricula around these requirements remains unknown. Just because the requirements exist does not mean that schools of education are aligned to the regulations.

School districts impact what teacher preparation programs do by exerting pressure to produce teacher candidates with certain skill sets to meet local needs. There have been reported cases of districts telling their local schools of education that they need teachers who know how to use data. Subsequently, the schools of education have had to revise components of their curricula to meet those needs. If more districts exert such pressure, the teacher preparation programs would be required to make the necessary changes.

Testing organizations in the United States produce tests that teacher candidates must pass to obtain their certification. We know that the three major tests, Praxis and NOTE produced by Educational Testing Service (Sykes & Wilson, 2015), and edTPA (SCALE 2013) have introduced components that require test takers to demonstrate their ability to use and knowledge of data use concepts. If the teacher candidates produced by schools of education cannot pass these tests, then there will be negative evaluative impacts on the institutions.

Professional organizations can leverage the importance of data literacy by impressing upon their members the need for educators to use data effectively and responsibly. In the United States, several professional organizations are advocates for data literacy. In particular, CAEP has taken real action to help convince deans of schools of education that data literacy is an essential skill set (Blue Ribbon Panel, 2010; Breaux & Chepko, 2015; Cibulka, 2013; Mandinach & Gummer, 2015). The National Board of Professional Teaching Standards has considered the inclusion of data literacy into the skill sets required of Board Certified teachers. The CCSSO (2012) has advocated for data literacy in national publications and through the InTASC standards (CCSSO, 2015) that lay out the performances, essential knowledge, and critical dispositions teachers need to demonstrate. The National Association of State

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Directors of Teacher Education and Certification (NASDTEC) has a responsibility for ensuring that data literacy becomes part of the certification and licensure requirements. Other organizations such as the American Association of Colleges of Teacher Education (AACTE) must take a more pro-active role with their members to communicate the importance of data literacy.

Professional development providers can assist schools of education through the provision of existing materials and resources. For institutions that do not have the capacity to teach about data, collaborations for online courses and MOOCs might be effective solutions. Using Data Project formerly at TERC has released a virtual course (see http://usingdata.terc.edu/workshops/online_courses.cfm). Harvard's Data Wise now has a MOOC (see http://edx.org).

A final player in the system is the U.S. Department of Education. Federal policymakers have made it known that teachers must use data and that education must become an evidence-driven profession. Yet the Department has done little to improve the capacity of educators to use data, short of providing the technological infrastructure at the state level to support data use. Nothing has been done to improve educators' capacity to use data, beyond speaking about the importance. Specific and sustained support from the federal level can help to improve how educators use data.

3.4. Next steps

There are several logical steps that extend from our empirical and theoretical work. First, there is a need for more research. We do not intend to have our conceptual framework be a static model. It will evolve and be modified over time as more knowledge of the field becomes further clarified. For example, in just a few years, data security has become a major topic in data-driven decision making. It is now essential to ensure that educators understand the importance of protecting the privacy and confidentiality of student data (Mandinach et al., 2015a; Phi Delta Kappa, 2015). It is likely that new skills will emerge over time. Second, research could inform the field about how best to address the differing needs of teachers and teacher candidates across the developmental career continuum. For example, how can data concepts best be taught as candidates are learning about pedagogy as opposed to teachers who are currently practicing. Third, research could address how role-based data literacy is; that is, how the knowledge and skill sets might differ for teachers, administrators, and other educators. Fourth, it is unclear what the continuum of data literacy looks like. We can likely identify novices. We can likely identify experts. The intermediary positions are less clear. Correspondingly, we suspect that not every educator must be an expert so knowing what a minimum acceptable level of data literacy looks like would be informative.

In terms of practical applications, schools of education will need assistance as they introduce data literacy into their programs. Faculty will need help as they plan how to integrate data literacy concepts into multiple courses. This will require retooling existing course materials. It will require faculty to acquire their own data literacy. The virtual course and the MOOC mentioned above can provide resources. However, we strongly advocate for the development of materials and resources that can be integrated into courses to minimize the potential resistance from faculty members.

Finally, it is important for a strengthening of the discourse and messaging around data literacy in teacher preparation programs to occur. Policymakers and other stakeholder groups should make it clear to schools of education that they must take action to help improve data literacy among educators and help them to understand their essential role. It is preferred that schools of education elect to modify their curricula rather having them buckle under accountability pressures. But change must happen. The old light bulb joke is relevant here. How many psychologists does it take to change a light bulb? One, but the light bulb must want to change. Change for schools of education will not come easily or in the near future. Schools of education are part of a larger and more complex system. The change can happen, but it should be because they want to change, rather than because they have to change to include data literacy in their teacher preparation programs.

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