

Preservice Elementary Teachers' Views of Their Students' Prior Knowledge of Science

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Abstract: Pre-service teachers face many challenges as they learn to teach in ways that are different from their own educational experiences. Pre-service teachers often enter teacher education courses with pre-conceptions about teaching and learning that may or may not be consistent with contemporary learning theory. To build on preservice teachers' prior knowledge, we need to identify the types of views they have when entering teacher education courses and the views they develop throughout these courses. The study reported here focuses specifically on preservice teachers' views of their own students' prior knowledge and the implications these views have on their understanding of the formative assessment process. Sixty-one preservice teachers were studied from three sections of a science methods course. Results indicate that preservice teachers exhibited a limited number of views about students' prior knowledge. These views tended to privilege either academic or experience-based concepts for different aspects of formative assessment, in contrast to contemporary perspectives on teaching for understanding. Rather than considering these views as misconceptions, it is argued that it is more useful to consider them as resources for further development of a more flexible concept of formative assessment. Four common views are discussed in detail and applied to science teacher education. © 2008 Wiley Periodicals, Inc. *J Res Sci Teach*

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Since the early 1980s researchers in science education have strived to understand common ideas about various scientific phenomena that students articulate in the classroom setting. Research on students' prior knowledge has been valuable for curriculum development and formative assessment practices focused on creating opportunities for students to articulate, use, and modify their ideas. If prior knowledge is a critical element of teaching and learning, then it is important for teacher educators to become aware of the types of prior knowledge their students, preservice teachers, have regarding the content of their teacher education courses. The research

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reported in this paper builds on the tradition of identifying common ideas that students articulate, but the focus here is on the types of common ideas that preservice teachers articulate regarding *teaching and learning science*. In particular, the research described in this paper investigates preservice teachers' views of elementary students' prior knowledge and the implications that these views have on preservice teachers' formative assessment practices.

Background and Theory

Role of Prior Knowledge in Contemporary Learning Theory

Eliciting and building on students' prior knowledge is a central tenet of learning theory associated with teaching for understanding (e.g., Bransford, Brown, & Cocking, 1999; Fosnot, 1996; Greeno, Collins, & Resnick, 1996). By eliciting prior knowledge, teachers can confront problematic student ideas and use vague but useful student preconceptions as seeds for what will become the intended learning outcomes (Hammer, 1996; Minstrell, 1991; McDermott, 1991; van Zee & Minstrell, 1997). This approach has been particularly influential in science education. Research in science education has identified several common ideas that students bring into the classroom and use in various contexts. Student ideas such as "motion implies force," "air pressure or rotation causes gravity," and "a shadow is an entity that travels through space" have been identified as ideas that are commonly articulated by students (AAAS, 1993; Driver, Guesne, & Tiberghien, 1985; Driver, Squires, Rushworth, & Wood-Robinson, 1994; Feher, 1990; Feher & Rice, 1988; Minstrell, 1991). Knowledge of common student ideas has allowed science teachers to anticipate the types of ideas that their own students might have. With these insights, teachers design programs and craft responses that provide opportunities for students to articulate and use these ideas, gather evidence that pertains to these ideas, and modify their ideas so they can become consistent with evidence (Brown & Clement, 1989; diSessa & Minstrell, 1998; McDermott, Shaffer, & Somers, 1994; Rochelle, 1998).

Terms such as misconceptions, alternative conceptions, and naïve conceptions have been used in the literature to characterize common student ideas that are inconsistent with scientific ideas. A conceptual change model, based on Piaget (1974) and Kuhn (1970), emerged in the literature in the early 1980s as a model for student learning requiring the replacement of misconceptions with formal concepts (Posner, Strike, Hewson, & Gertzog, 1982; Strike & Posner, 1992). This model of conceptual change promotes a *confront-resolve-replace* approach to instruction, where students' misconceptions are confronted with discrepant events and are given the opportunity to replace their misconceptions with the more useful formal concept.

Redefining Prior Knowledge

Science education researchers and researchers in cognitive science have proposed that it is misleading to characterize students' representations, problem solutions, and articulations as stable, large-scale *misconceptions*. These researchers offer a *resource* model for understanding what students articulate in classroom situations (diSessa, 1988; Hammer, 1996; Hammer, Elby, Scherr, & Redish, 2004; Smith, diSessa, & Rochelle, 1993). They argue that many of the ideas that students articulate are not used consistently among a variety of contexts and therefore should not be characterized as stable misconceptions. Instead, these researchers have found that while students articulate answers that are incorrect, many sensible and correct features exist within their answers. For example, when a student states that the second bulb in a series circuit will be dimmer than the first bulb "because the first bulb in the circuit used up some of the electricity," a teacher

might dismiss the comment as the misconception that *current is used up*. A teacher using a resource model might instead view this comment as a preliminary version of energy transformation; indeed, something is “lost” from the circuit as current flows through the first bulb. This idea that “something is lost or changed” could be used by the teacher to help the student distinguish between energy and current. Instruction that relies on the confront-resolve-replace model may fall short in recognizing the value of students’ ideas for further instruction.

Formative Assessment and Prior Knowledge

The formative assessment process relies on the teacher’s recognition of potentially useful ideas that students articulate. Atkin, Black, and Coffey (2001) proposed a model of formative assessment consisting of goal identification, assessment, and feedback. More specifically, assessment is formative when the information derived from the assessment informs instructional practices in order to meet student needs (Black & Wiliam, 1998). According to Atkin, Black, and Coffey, formative assessment is the process of teachers asking themselves about the students: “Where are you trying to go?” “Where are you now?” “How can you get there?” This classroom process takes place between a teacher and students and can help students gradually align their conceptions with observational evidence and with generalized ideas held by the scientific community. Figure 1 represents a formative assessment model adapted from Sadler (1989) and Atkin et al. (2001). The top arrow shown in Figure 1 is intended to illustrate the cyclical nature of the formative assessment process where the teacher repeats the process continually throughout instruction. The formative assessment process is *responsive* in the sense that the teacher responds to the assessment of students’ prior knowledge by setting intermediate goals, making instructional decisions, and providing feedback and relevant instruction. The term feedback in the context of science inquiry-based classrooms is more specific than the meaning of feedback in models of learning such as the IRF (Initiation, Response, Feedback) in that the feedback must make instructional use of the content of the student’s response, for example, by asking whether the student has evidence to support a particular claim. Feedback, as represented in Figure 1, is not evaluative in the sense of stating that an answer is correct or incorrect. The model of formative assessment described in Figure 1 is consistent with the ESRU model (Elicit, Student response, Recognize student response, and Use student response) (Ruiz-Primo & Furtak, 2007). As is the case with the ESRU model, the formative assessment model described below depends upon the *use* of students’ ideas as the materials from which a teacher’s responses are formed.

In order for the formative assessment process to work, the teacher must be skilled in recognizing the ideas that students articulate as resources for further learning and must craft activities and responses that can help the learner become aware of and build his or her own ideas. The formative assessment process requires that the teacher understands that there are many

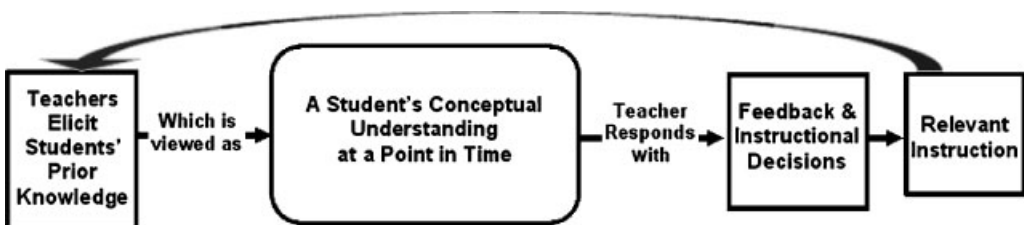


Figure 1. A cyclic model of formative assessment.

intermediate knowledge states that may look wrong in comparison to the accepted scientific concept but may represent steps in the process of coming to understand that concept. Therefore, the first step in the formative assessment process is understanding what constitutes students' prior knowledge.

Prior knowledge has been defined in the literature as consisting of both knowledge developed from formal learning situations and self-taught knowledge drawn from students' experiences (Shepard et al., 2005). This definition is further elaborated below through the lens of Vygotsky's theory of concept formation.

Vygotsky's Theory of Concept Formation and Prior Knowledge

Vygotsky's work entails more than is presented here. Part of the value of Vygotsky's work is that it connects social elements of cognitive development to individual elements of cognitive development. In this section, Vygotsky's theory of concept formation is used to characterize and further articulate the nature of prior knowledge.

According to Vygotsky's (1986) theory of concept formation there exist two different types of concepts within the cognitive processes of a learner: (1) spontaneous or experience-based concepts and (2) scientific or academic concepts introduced by the teacher, books, and other sources.¹ Vygotsky, following Piaget (1929), differentiates between these two types of concepts. Piaget's theory that is often linked to the conceptual change model (Strike & Posner, 1992) focuses only on the development of students' experience-based concepts that are the starting point in the confront-resolve-replace approach. Within the conceptual change model little is said about the process by which the academic concept is actually *learned*. In contrast, Vygotsky describes concept formation by considering both experience-based and academic concepts as playing mutual, *active* roles in the learning process. According to Vygotsky's theory, academic concepts and experience-based concepts have different roots in the mental processes of the learner and work together to produce a learner's conceptual understanding at a point in time.

As academic concepts are introduced, often in formal learning environments, a learner filters interpretations of academic concepts (including terminology and symbols) through his or her experience-based understanding of the world. At the same time, the learner's experience-based concepts evolve as he or she attempts to cast them in the form of academic language. Through this process, learners try out academic language presented through schooling, increase awareness of their own experience-based concepts, and begin to develop academic language that allows them to generalize experience-based concepts beyond the concrete experiences to which they were tied. The center box in Figure 2 illustrates the process of concept formation as the co-mediation of experience-based concepts (EBCs) and academic concepts (ACs). This co-mediation is viewed as

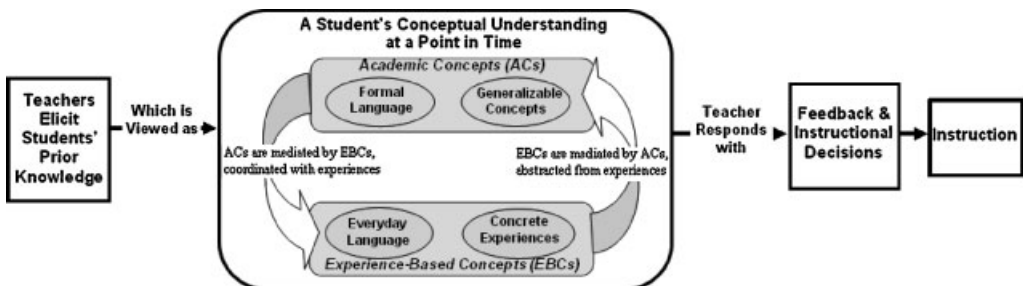


Figure 2. Flexible formative assessment model. Prior knowledge is viewed as consisting of ACs and EBCs that mediate one another.

a student's conceptual understanding at a point in time. The center box in Figure 2 illustrates that two processes occur together as learners appropriate the knowledge of a discipline by creating meaning through their own lived experiences.

A student's experience-based concepts are used to *mediate* the development of academic concepts, serving as a lens through which to interpret the terms, notational systems, and concepts typically introduced in a classroom setting. Similarly, academic concepts are used by the student to *mediate* the process of bringing experience-based concepts into conscious awareness and to generalize these concepts so that they are applicable to a greater variety of circumstances. This process of co-mediation often results in hybrid ideas that do not look like either the original experience-based concepts or the formally taught academic concepts. This prior knowledge may therefore appear to be vague, fragmented, and even bizarre to the teacher, but nonetheless represents a stage in the process of appropriating the language and concepts of science.

As an example of a hybrid idea consider a student who says that "the force of a kick was transferred to a soccer ball, and the ball stops when the force runs out." The statements "force is transferred" and "force runs out" are not aligned with academic concepts of *force* and may be interpreted by the teacher as incorrect or as a misconception. A physicist would talk about *energy* being transferred or transformed. While the student in this example may have been using the term *force* in the way that a physicist does (as a push, pull, or interaction), it is just as likely that the student was instead drawing on an experience-based understanding of energy and using the word *force* because this is the term that was being promoted in the formal learning environment. This student has mediated the formal term *force* through the lens of his experiences involving things stopping when something runs out (e.g., gas, air, batteries). This example illustrates the process of concept formation, where a learner attempts to utilize the academic language being promoted in class and does so through the lens of his or her own experiences relevant to the topic. In contrast, a student may articulate the full academic definition of a scientific term with few conceptual connections to either his or her own experiences or to the generalized academic concept to which this term is tied. Further, a student may articulate a reasonable understanding of a phenomenon or concept without using scientific language. In all cases, the process of formative assessment is necessary for helping students connect their understandings of a concept, a term, their own experiences, the nature of science, or their role as a student in a science course, to where we, as teachers, would like them to be. Hence, a teacher must be able to define *prior knowledge* flexibly as consisting of academic concepts, experience-based concepts, and hybrid concepts as they may exist along a trajectory of conceptual development. If the concept is not defined flexibly, a teacher may be limited to assessments that access only whether students are able to state sentences that sound correct. In such a case, a teacher would miss the valuable experience-based concepts that learners bring to the situation and the meanings that students attribute to the formal language.

Content Knowledge

Understanding and enacting the formative assessment process depends on a teacher's ability to recognize science knowledge in statements that elementary children make, even when these statements contain few science words. Hence, the teaching of science, or any subject, is largely dependent upon the teacher's understanding of the continuity and connections of concepts within that discipline as well as how these concepts relate to everyday life (Ball, 2000; Ball & Bass, 2000; Borko & Putnam, 1996). The notion that subject matter knowledge should be considered together with pedagogical knowledge was termed *pedagogical content knowledge* by Shulman (1986, 1987) and further investigated by others (e.g., Ball, Lubienski, & Mewborn, 2001; Gess-Newsome

& Lederman, 2001; Grossman, 1990; Nathan & Petrosino, 2003). Unfortunately, many undergraduate students (science majors as well as nonmajors) leave their science courses with a conception of science as a set of disconnected facts, symbols, and language to be memorized (Hammer, 1994). College students fail to learn (and courses fail to teach) the social origins and tentative nature of science knowledge in undergraduate science courses, yet contemporary models of teaching for understanding depend upon these concepts (National Research Council, 1996). Hammer (1994) identified a set of beliefs held by students before, during, and after participating in an undergraduate physics course. This research demonstrated that many students leave their undergraduate physics courses with an understanding of physics as a collection of fragmented facts and symbols, not as part of a coherent whole or connected to everyday life. The study showed that students often believe that physics knowledge must come from some authoritative source; the teacher must give students their science knowledge.

If preservice teachers conceive of science as a set of facts provided by authority, their understanding of the concept and utility of their students' prior knowledge and its role in the formative assessment process could be greatly affected. As will be further articulated in the research presented in the following section, preservice teachers attempt to utilize the academic term *prior knowledge* even before they fully understand it. For example, in a written report of a lesson implementation, a preservice teacher wrote, "After I gave students their prior knowledge, I continued with the lesson." Here, the preservice teacher has attempted to use the academic term prior knowledge but has filtered it through her understanding of science as a set of facts provided by an authority and her understanding of learning as the process by which the teacher provides necessary background information to students. The preservice teacher in this example may have drawn on her experiences of learning as a student who took notes while the professor provided the scientific knowledge of the course. The preservice teacher in this example attempted to utilize the academic term *prior knowledge*, and did so through the lens of her own experiences of learning in a traditional, lecture-style classroom.

Helping preservice teachers prepare to enact the formative assessment model may require that we, as teacher educators, develop our own understanding of the types of common ideas that preservice teachers bring to science methods courses with respect to the concepts that we are trying to teach. The study presented here investigated preservice teachers' views of elementary students' prior knowledge and the implications of these views in their enactment of the formative assessment process. The specific research questions were

1. What are preservice teachers' views of prior knowledge at various points throughout a semester; that is, how do they use the term in the context of a science methods course?
2. How do preservice teachers' views of prior knowledge impact their formative assessment practices?

Identifying common views that preservice teachers articulate in the teacher education environment can help teacher educators design curricula relevant to preservice teachers' prior knowledge about teaching and learning science. The research described in this paper was designed to identify common views among preservice teachers in the context of a teacher education program.

Method and Data Sources

Context of the Study and Participants

Participants in this study were preservice elementary teachers enrolled in a four-semester licensure program leading to certification and a Master of Arts degree in Instruction and

Curriculum. The aims of the program included teacher preparation for urban and rural communities with high proportions of at-risk populations and limited proficiency in English. Pre-service teachers were assigned practicum placements in both primary and intermediate grades over two semesters. After two semesters of coursework and practicum placements, preservice teachers completed a semester of student teaching which was followed by a final semester of courses. The school district that partnered with this program was in an urban setting with 57% Hispanic, 19% Black, 1% American Indian, 3% Asian, and 20% Caucasian student population. Twenty percent of the students in this district were in English Language Acquisition programs. Sixty-three percent of the students received free or reduced-price lunch.

The study group consisted of 10 males and 51 females, 4 of whom were Hispanic, 1 Asian, and 56 Caucasian, with ages ranging from 23 to 40. This group was above average in academic performance with cumulative undergraduate grade point averages of 3.0 or greater.

Data

Pre-service teachers ($N = 61$) participated in the coursework under investigation during their second semester of a four-semester licensure program. The data for this study were derived from three sections of an Elementary Science Methods course taught in three consecutive years by the same instructor (first author) using the same class design, materials, and assignments. All three sections (approximately 20 students per course) followed a similar course structure and all included an identical semester-long, practicum-based assignment. The primary data source for this study was a cumulative, six-part, semester-long assignment designed to meet learning objectives of the Elementary Science Theory and Methods course as well as the state's performance-based standards for teachers.

The semester-long assignment was a research-based assignment where preservice teachers were expected to design and implement lessons and assessments, collect and analyze pre- and post-assessment data (both qualitatively and quantitatively), and make instructional decisions and recommendations on the basis of these data. The purposes of the assignment were for preservice teachers to:

- Recognize that elementary students have prior knowledge relevant to science objectives and standards. This prior knowledge may come partially from informal experiences and partially from previous instruction.
- Recognize that elementary students' prior knowledge is valuable for further learning and should be used by the teacher directly or indirectly in instruction.
- Learn methods for analyzing assessment data both qualitatively and quantitatively and use assessment results to make instructional decisions and plans.

The six stages of the assignment (parts A through F) were turned in at various points throughout the semester and were returned to students with substantive written instructor feedback. Written formative feedback and scores for each stage of the assignment were based on a list of criteria that was provided to preservice teachers several weeks before each stage of the assignment was due. These criteria are shown in the first column of Table 1. As shown in Table 1, part A begins with preservice teachers generally describing the topic they were going to teach in their field-based practicum class. By the time they reach part F, the preservice teachers have designed, modified, and taught a lesson and analyzed assessment data both qualitatively for common and idiosyncratic ideas that their students expressed and quantitatively to compute learning gains. The *feedback* column in Table 1 represents the types of feedback that were

Table 1
Semester-long, multistage, practicum-based assignment

	Instructor's Evaluation Criteria	Written Instructor Feedback
Part A week 2	<ul style="list-style-type: none"> • Science topic and content to be addressed • What you feel you still need to learn about the topic • Relevance of topic to children's lives • Connections to other subjects (e.g., language arts) 	<ul style="list-style-type: none"> • Suggestions for narrowing topics and standards • List of resources for learning more about the topic
Part B week 4	<ul style="list-style-type: none"> • Goals for the unit • Objectives for a lesson that will be implemented • Anticipated student prior knowledge using literature in science education (e.g., American Association for the Advancement of Science, 1993; Driver et al., 1985) • Initial pre and post-assessment plans to be used qualitatively to elicit students' conceptions relevant to objectives and quantitatively to show student learning gains in part D 	<ul style="list-style-type: none"> • Suggestions specific literature on student prior knowledge • Suggestions for narrowing learning objectives • Suggestions for refining assessment plans • Suggestions for creating rubrics based on anticipated student knowledge
Part C week 5	<ul style="list-style-type: none"> • Modified unit goals and related standards • Initial outlined unit plan • Modified pre/post-assessments and rubric • Initial detailed lesson plan to be implemented 	<ul style="list-style-type: none"> • Suggestions for refining lessons to reflect objectives • Suggestions for modifying assessment questions
Part D week 8	<ul style="list-style-type: none"> • Qualitative analysis of pre-assessment data, identifying and classifying common and idiosyncratic conceptions that appeared in elementary students' work • Lesson plan modified on the basis of pre-assessment data analysis • Samples of pre-assessment data 	<ul style="list-style-type: none"> • Critical examination of pre-assessment analysis • Suggestions for organization and representation of assessment data • Suggestions for modifications and differentiation
Part E week 14	<ul style="list-style-type: none"> • Analysis of post-assessment data • Quantitative analysis of learning gains for each student and quartiles, according to objectives • Interpretation of data for informing instruction • Modified lesson or unit reflecting data analysis • Plans for differentiation on the basis of analysis • Samples of post-assessment data 	<ul style="list-style-type: none"> • Critical examination of post-assessment analysis • Suggestions for noticing trends in qualitative and quantitative data • Suggestions for interpreting learning gains for instruction
Part F week 15	<ul style="list-style-type: none"> • Description and reflection on the implementation • Modified pre- and post-assessment plan • Modified lesson to reflect changes in thinking • Reflection on the semester-long assignment 	<ul style="list-style-type: none"> • Suggestions for future implementations of the lesson • Reflection on pre-service teacher growth

provided by the instructor, although not all types of feedback were provided for all preservice teachers. Feedback was tailored to the specific needs inferred by the instructor for each preservice teacher. A typical example of written feedback for a preservice teacher who was struggling with assessment questions is provided in the Appendix.

Parts A through F of the assignment provided several opportunities for preservice teachers to reveal the way they were thinking about student prior knowledge and its role in the formative assessment process. The field-based component of the assignment provided opportunities for students to try out the ideas they articulated in their initial lesson plans and assessments. Parts D through F consisted mostly of the same elements as parts A through C (objectives, standards, unit and lesson plan, and assessments) except that they were retrospective and turned in *after* preservice teachers implemented their lessons in an elementary classroom and after they had analyzed pre/post-assessment data. Therefore, parts A through C were generally considered “initial measures” of preservice teachers’ views about student prior knowledge. Parts D through F were generally considered “final measures” of preservice teachers’ views because they were turned in during the last few weeks of class, *after* preservice teachers implemented their lessons and analyzed assessment data.

Analysis and Coding Scheme

The data were analyzed in three phases. In Phase I of the analysis preservice teachers’ written assignments were each coded to determine the meanings that preservice teachers appeared to attribute to the concept of prior knowledge. These meanings were inferred from actual statements such as, “students did not know anything about ecosystems.” Meanings that preservice teachers attributed to prior knowledge were also inferred from the foci of their pre-assessments and rubrics and from their analysis of assessment data. Initial analyses of the data revealed that preservice teachers tended to privilege *either* academic concepts or experience-based concepts when eliciting and responding to students’ prior knowledge. Therefore, academic concepts and experience-based concepts have been analytically separated although this study does not promote the view that either exists as an isolated entity in the cognition of the learner (see Figure 2). Coded data were therefore grouped and categorized in terms of whether preservice teachers appeared to view students’ prior knowledge in terms of Academic Concepts (ACs), Experience-Based Concepts (EBCs), or both.

In Phase II of the analysis, the data (parts A through F for each preservice teacher) were re-analyzed to determine how the preservice teachers responded to their interpretations of students’ prior knowledge or how they included their anticipated student prior knowledge in their instructional plans. In this phase of the analysis, the meanings that preservice teachers attributed to the notion of prior knowledge (inferred from Phase I) were connected to the ways in which they responded (or did not respond) to their students’ prior knowledge as documented by the pre-assessment. Phase I and Phase II were first conducted with data from 22 preservice teachers in the first year of the study. Codes that emerged from the first set of data were then applied to data from two other sections of the course (from two subsequent years). These codes were refined and resulted in four categories that were found to be common in all three data sets. These common categories were considered common preservice teachers’ views of prior knowledge and its role in the formative assessment process. Four categories recurred throughout all three data sets. Each category was inferred for at least 30% of preservice teachers. In some cases preservice teachers’ work did not mention students’ prior knowledge or how they would respond to prior knowledge; or they mentioned it only once, not enough to convince the researchers that any code was appropriate. This work was classified as “no code.”

In Phase III of the analysis, parts A through F of each preservice teacher’s assignment were compared to one another to determine consistency or changes in each preservice teacher’s views. Throughout this analysis, preservice teachers were found to either change their views or maintain the same views throughout the semester. In most cases of change, preservice teachers’ views were

found to be different before and after they implemented the lesson and analyzed assessment data. Views of the formative assessment process were therefore grouped into initial (typically parts A–C) and final (parts D–F) measures.

Reliability

Coding reliability was determined in two phases. First, initial categories that emerged from the data set from the first year of the study were generated and agreed upon by two instructors who had the same preservice teachers in their courses and had the same semester-long assignment. The coding scheme was then refined as it was used, and applied to the analysis of the other two data sets. The final codes were then given to an external reviewer along with a sample of the data (approximately 10% of the total data set). The external reviewer returned the coded data initially with a 71% match. After negotiations regarding the meanings of the codes, a new random sample of the data (approximately 10% of the total data set) was given to the external reviewer and was recoded. A 100% match was obtained between the researchers' codes and the external reviewer's codes in the second sample of data.

Triangulation

The data described above were augmented with field notes from observations of a sample of preservice teachers ($n = 18$) as they implemented their lessons in the elementary classroom. Classroom observation data were used to determine the consistency between what preservice teachers reported they did when they implemented their lessons in their field sites and what they actually did. For all teachers in the observation sample, reports of their lesson implementation were closely aligned with the field notes from observations. This form of triangulation assured us that written parts D through F were not merely representations of what preservice teachers thought their science methods instructor wanted to hear.


Findings

The science units proposed and implemented by participants spanned a range of grades (from 1st through 6th) and science topics. Specific lessons spanned topics in life science, earth science, space science, physics, and chemistry. Instructional methods ranged from experimentation, demonstrations, group work, whole-class discussions, and lectures. Common views identified for preservice teachers are discussed below. Rather than conceiving of the less-flexible views as preservice teachers' misconceptions about prior knowledge and formative assessment, it is more useful to consider them as hybrid conceptions that could be useful for further development of the more-flexible concept of formative assessment.

Pre-service Teachers' Views of Formative Assessment and the Role of Prior Knowledge

Four common views of formative assessment and the role of students' prior knowledge emerged from the data. Each view is described in Figure 3 and briefly defined below.

- (a) In the Flexible view, preservice teachers viewed prior knowledge as consisting of ACs, EBCs, and hybrids in both their elicitation of, and responses to, prior knowledge (see Figure 2 above).



View	What do teachers elicit? (their views of prior knowledge)	What do teachers respond to?	What drives feedback and instructional decision making?	What are teachers' instructionally relevant responses?
EBC view	EBCs (Experience-Based Concepts)	Nothing	Students have EBCs relevant to lesson objectives. EBCs are not recognized as relevant for instruction beyond the elicitation phase.	Teach pre-planned lesson with no modifications.
Get It Or Don't view	ACs (Academic Concepts)	ACs	Students either get the academic objective or they don't. EBCs are not considered as relevant in most aspects of instruction (including elicitation phase).	Teach pre-planned lesson if students lack formal concept, or do not teach it if they demonstrate formal language and concepts.
Mixed view	EBCs or hybrids	ACs	Students have relevant EBCs and hybrids (these are elicited but not used). Students either get the academic objective or they don't. EBCs and ACs are considered separate entities relevant during different aspects of instruction.	Teach pre-planned lesson if students lack formal concept, or do not teach it if they demonstrate formal language and concepts.
Flexible view	ACs, EBCs, hybrids	ACs, EBCs, hybrids	ACs and EBCs are considered integrated.	Modify lesson or unit to incorporate students' prior knowledge and create learning opportunities for all students.

Figure 3. Pre-service teachers' views of the formative assessment process. The vertical arrow on the left represents the level of responsiveness of each view.

- (b) In the EBC view, preservice teachers tended to privilege EBCs over ACs during the elicitation phase of instruction and did not respond to the EBCs elicited (see Figure 4).
- (c) In the Get It Or Don't view, preservice teachers tended to privilege ACs over EBCs during all phases of instruction (Figure 5).
- (d) In the Mixed view, preservice teachers tended to privilege EBCs during the elicitation phase of instruction but privileged ACs when creating an instructional response (Figure 6).

In Figure 3, the views are organized in rows according to the level of preservice teachers' responsiveness to the prior knowledge they elicited. For example, the EBC view was least responsive because preservice teachers who exhibited this view elicited but did not respond to students' prior knowledge. The Flexible view is most responsive because these preservice teachers' responses were tailored to the prior knowledge they elicited. The Get It Or Don't and Mixed views were partially responsive because the preservice teachers responded only to whether or not the students articulated the correct answer. The columns in Figure 3 compare the four views in terms of the types of knowledge the preservice teachers elicited (EBCs, ACs, or hybrids), the

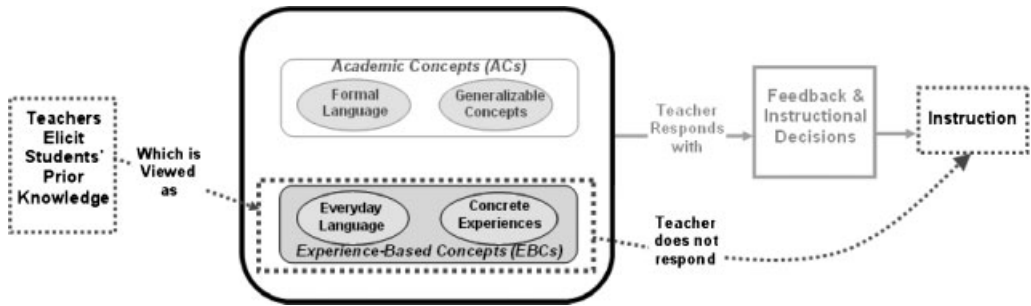


Figure 4. EBC view of formative assessment. EBCs are privileged over ACs.

type of thinking that seemed to drive their feedback and instructional decision making, and the types of responses that preservice teachers tended to provide to students. Figures 4 through 6 provide another representation of these views and should be compared to one another and to Figure 2 (the flexible formative assessment model) in terms of the knowledge that is privileged in different points of an instructional sequence according to the view represented by each figure. In Figures 4 through 6, the parts of the formative assessment process that were not accessed are shown in gray.

The number of preservice teachers that were coded as expressing each of these views in initial and final measures is shown in Table 2. Initial measures are shown in rows and final measures are shown in columns. Each preservice teacher who participated in the study is represented in this table, and how each preservice teacher’s view differed in initial and final measures is shown.

As shown in Table 2, only 28% of the preservice teachers in this study demonstrated a Flexible view by the end of the methods course, although most (72%) experienced some form of transition in their views of prior knowledge and its role the formative assessment process from initial to final measures. For example, the small numbers of EBC codes in final measures (3% of all codes) in comparison to the relatively large numbers of EBC codes in initial measures (30%) demonstrates that many preservice teachers moved from the nonresponsive EBC view to one of the three responsive views. Specific details regarding the process of change from initial to final views for each preservice teacher are beyond the scope of this paper. The focus here is on the prevalence of each view, which is represented in both quantity and percentage in the rightmost column (for initial measures) and in the bottom row (for final measures) in Table 2. The numbers along the diagonal of Table 2 represent the 17 (28%) preservice teachers who were coded with the same view

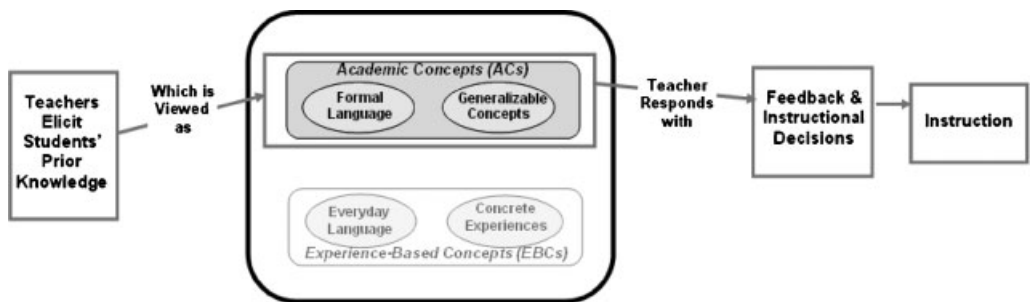


Figure 5. Get It Or Don't view of formative assessment. ACs are privileged over EBCs.

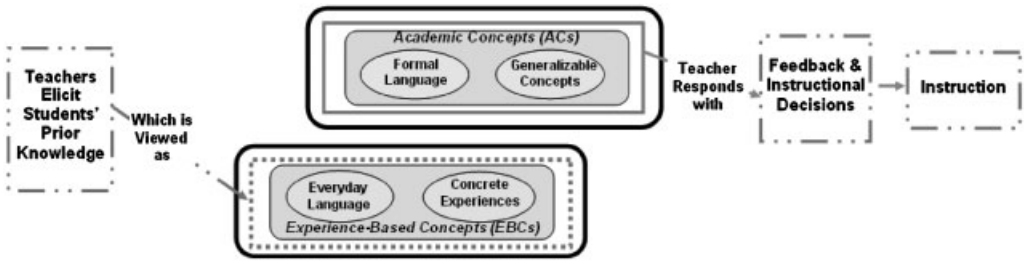


Figure 6. Mixed view of formative assessment. ACs and EBCs are both recognized but are considered separate entities serving different purposes during different aspects of instruction. EBCs are privileged during elicitation, ACs are privileged during response and instruction.

in both initial and final measures. When these views are counted only once for each preservice teacher, a total of 20 (33%) of the preservice teachers in this study exhibited the Flexible view in either initial or final measures, 19 (31%) exhibited the EBC view, 30 (49%) exhibited the Get It Or Don't view, and 32 (53%) exhibited the Mixed view in either initial or final measures. Thus, these views may not be idiosyncratic and may be prevalent among preservice elementary teachers in the context of a teacher education program.

These four common views characterize how preservice teachers articulated and enacted their understanding of students' prior knowledge and how this understanding impacted their notions of the formative assessment process. In the remainder of this paper, the four common views are described in detail with a typical example from each view that illustrates the type of data from which these codes were generated. While each of these views represents a legitimate aspect of the formative assessment process, only the Flexible view represents the complex formative assessment process described earlier in this paper.

The Flexible View

The Flexible view represents the formative assessment process described in the preceding section and throughout teacher education literature (Atkin et al., 2001; Shepard et al., 2005). Research has shown that teachers who elicit, recognize, and actually use students' ideas in their instruction show greater student achievement than those who do not (Ruiz-Primo & Furtak, 2007). Pre-service teachers who were coded with this view elicited, described, and responded to (or described how they would respond to) students' prior knowledge with respect to an objective.

Table 2
Frequencies (and percentage) of codes assigned to initial and final work submitted by pre-service teachers (N = 61)

Final View → Initial View ↓	EBC	Get It Or Don't	Mixed	Flexible	No Code	Total Initial (%)
EBC	1	6	5	6	0	18 (30)
Get It Or Don't	1	6	11	1	0	19 (31)
Mixed	0	3	5	4	0	12 (20)
Flexible	0	0	3	5	0	8 (13)
No Code	0	2	1	1	0	4 (6)
Total final (%)	2 (3)	17 (28)	25 (41)	17 (28)	0 (0)	61 (100)

Initial measures are shown in rows, final measures are shown in columns.

These preservice teachers viewed prior knowledge flexibly as consisting of EBCs, ACs, and hybrids. When responding to ACs they also accounted for EBCs. An example of a preservice teacher who was coded in final measures with the Flexible view follows.

Example of the Flexible View

Katie was a preservice teacher who taught a lesson on *Whale Blubber* in her first-grade practicum classroom. She hoped that students would learn that whale blubber is a layer of fat and that whales need blubber for warmth and survival in their habitat. In her pre-assessment, Katie asked her students two questions: (1) What is whale blubber? and (2) Why do whales have blubber? In her initial analysis of her pre-assessment data, Katie listed actual children's statements such as blubber is "a tail," "krill," "helps the whale feel well," "keeps them alive," "is fat," and that whales use blubber "to eat," "to drink," "to breathe," "to splash," and "to keep them warm." She initially concluded that the children knew very little about the topic she was going to teach. After instructor feedback² regarding her data analysis, Katie reclassified her pre-assessment data into the categories presented in Table 3.

She went on to describe her data in terms of what the children *did* understand about the topic she was going to teach (body parts, functions, and animal needs). In her final report she said, "I learned that just because a student doesn't know the term blubber, doesn't mean that they don't know that whales have characteristics to allow them to survive in their environment."

Katie realized that while her students were unable to articulate the correct academic concept that was the objective of her lesson, they did understand many relevant aspects of the topic. Although Katie did not modify her lesson plan,³ she modified her unit and how she would connect the lesson to students' prior knowledge in the future. She described how she would change her focus from a lesson in which students defined the term "blubber," to a lesson that focuses an animal's *need* to stay warm and how specific *body parts* and the *functions* of these body parts can help them meet that need. She included in this an initial lesson that would help students generalize and categorize what they already seemed to understand into categories such as functions, body parts, and needs. She also modified her pre-assessment to include a question on how children stay warm in the winter and how they think animals, who don't have any clothes, stay warm. In this case, Katie recognized, described, and used students' prior knowledge to inform her instruction.

In the example above, Katie learned from her assessment data. She learned that her students had many good ideas regarding the science concepts she wanted to teach and she made changes to her thinking as a result. In addition, Katie learned that teaching and learning science is more than definitions of terms and that academic concepts can have relevance to students' lives. Pre-service teachers like Katie who were coded with demonstrating a Flexible view were responsive to their interpretations of students' prior knowledge either in what they actually did when implementing their lessons or in what they said they would do in future implementations.

Table 3

An example of a Flexible view of prior knowledge: Katie's reanalyzed pre-assessment data (n = 22)

Students Thought That Whale Blubber Is: n (%)	Students Thought the Purpose of Blubber Is: n (%)
Body parts (nose, skin, whale) 11 (50)	Functional (keeps warm) 6 (26)
Fat or Goo 5 (23)	Basic needs (food, drink, breath) 9 (43)
Functional (keep alive, feel well) 3 (14)	Functional other (helps live, splash) 5 (23)
Stuff found on whale (krill) 1 (4)	Whales have blubber 1 (4)
Not readable 2 (9)	Not readable 1 (4)

The Experience-Based Concepts (EBC) View

Like the Flexible view, the EBC view describes preservice teachers who provided rich descriptions of the types of ideas that their students articulated. In contrast, those coded with the EBC view were *nonresponsive* to what they elicited as students' prior knowledge (typically EBCs). These preservice teachers elicited, described, and appeared to value the experiences that their students had (or may have had), but these preservice teachers did not respond to their interpretations of students' prior knowledge in their instruction or in descriptions of how they might change their instruction for the future. Instead, after describing their students' ideas, they went on to teach their lessons as planned with no modifications on the basis of assessment data. These preservice teachers did not seem to draw connections between assessment data and instructional practice. An example of the EBC view follows.

Example of the EBC View

Sara designed a unit and taught a lesson on *Animals and Their Needs* in her first-grade practicum placement. In part C of her assignment, Sara stated the following goals: (1) students will know that animals eat plants and/or other animals to live, (2) students will understand the meaning of the terms herbivore, omnivore and carnivore, and (3) students will understand that an animal's teeth affect what they are able to eat. Sara's pre-assessment was designed to elicit students' ideas about what various animals eat. She carefully selected an animal to represent each of omnivore, herbivore, and carnivore (although she did not use these terms in the pre-assessment). She asked students to draw what they thought a skunk, a deer, and a snake eat. Sara's analysis of her pre-assessment data consisted of actual statements that the students made and a table that showed each of her students' answers to each of the three questions. In her analysis, Sara recognized that "most students already know that animals eat either plants or meat." A summary of Sara's assessment data is shown below.

Assessment Questions	Student Responses
(1) What do you think skunks eat? (<i>Omnivore</i>)	Meat, plants, trash
(2) What do you think deer eat? (<i>Herbivore</i>)	Meat, grass, plants
(3) What do you think rattlesnakes eat? (<i>Carnivore</i>)	Meat, insects, rats

A majority of Sara's students (84%) expressed both meat (including bugs, animals, and rats) as well as plants (including trees, berries, and grass) in their answers to the questions. Sixteen percent of Sara's students mentioned only plants or only animals in their answers to all three questions. Sara understood that that her students already knew that animals eat either plants or meat and that this understanding could be useful for further instruction. She could have modified her lesson or added a lesson that could help her students associate the terms *omnivore*, *herbivore*, and *carnivore* with what the students already understood about plants and animals as food sources. Further, she could have created a preliminary lesson that would help first graders generalize and categorize their statements about bugs, insects, and rats as *meat*; and grass, berries, and trees as *plants*, which could lead to a lesson that associates terms with animals that eat meat, plants, or both. In addition, Sara's data shows that many students (13 of 25) said that snakes eat small things such as insects or rats and three students said that skunks eat trash. These findings could lead to the inference that a portion of the class was already attributing physical characteristics (stinky for the skunk and small for the snake) to the types of food that animals eat.

However, Sara did not use her data to inform her instruction. Instead, she went on to teach the same lesson that she developed *before* analyzing her assessment data. Sara's lesson consisted of showing these first-grade students a set of 10 cards with pictures of various animals within each category. The first set of cards depicted omnivores, and students were asked to "pick out patterns that they see." In Sara's written work, she explained that she hoped students would notice that "animals with horns/hooves, animals that look like horses, and butterflies/moths" are omnivores. She then showed students a set of carnivores and asked students to "pick out patterns that they see." She wrote that she hoped students would notice that "cats, dogs, owls, snakes, spiders, large birds, and birds with sharp beaks" tend to be carnivores. None of the cards that Sara used showed the animals' teeth. It is not clear how this lesson would help students build a bridge between where they were conceptually (understanding that animals eat either plants, animals, or both) and where they were going (distinguishing between meat and plant eaters and those that eat both, tying what animals eat to academic terms, and seeing how different types of teeth may relate to what an animal eats). Sara's case is representative of all of the preservice teachers who were coded with the EBC view in initial or final measures. In each case, they elicited, described, and appeared to value their students' prior knowledge, but they did not *respond* to this information in their instruction. Eliciting, describing, and valuing students' EBCs is a critical aspect of the formative assessment process. Thus, the EBC view may represent one step in the process of coming to understand the more complex process of formative assessment.

In contrast to the EBC view, the Get It Or Don't view (described below) was responsive in the sense that preservice teachers coded with this view respond to *their interpretations* of students' prior knowledge, although these interpretations did not include EBCs. A central difference between the Get It Or Don't view and the EBC view is that those coded with the EBC view asked, "What *do* they get?" and those coded with the Get It Or Don't view asked, "Do they get the academic concept and/or terminology or not?" Clearly, both of these questions are integral facets of the formative assessment model, but neither on its own represents the flexible formative assessment process.

The Get It Or Don't View

The "Get It Or Don't" view of formative assessment defines prior knowledge as consisting only of correct, academic concepts, usually with the correct academic language. There were two types of Get It Or Don't views which differ from one another but frequently occurred together: (1) a "vocabulary-based" view and (2) a "previously taught" view. The vocabulary-based Get It Or Don't view defines prior knowledge in terms of the correct academic language associated with the scientific term. For example, if elementary students were unable to articulate that "matter is anything that has weight or takes up space," the preservice teacher concluded that they "knew nothing about matter." In this example, the preservice teacher did not consider children's experiences with icicles, mud, water, steam, and other examples of matter they had experienced throughout their lives.

The "previously taught" Get It Or Don't view also defined prior knowledge in terms of correct, academic concepts; but according to the previously taught Get It Or Don't view, the definition of prior knowledge was limited to content that was the subject of previous instruction. In this view, if a science topic was taught in a previous grade level, then the preservice teacher seemed to think that the concept was learned accurately and completely by the students and therefore the students had prior knowledge of the subject. Alternatively, if the subject was not taught in a previous grade level, then preservice teachers coded with this view assumed that the students

likely had no prior knowledge of the subject. For example, a preservice teacher wrote about fourth-grade students, “I know they will not have any prior knowledge about ecosystems because it was not taught in the third grade.” This statement does not consider the role of children’s experiences with fish living in water, bees and flowers, and different types of trees in Mexico and Colorado in shaping their prior knowledge relative to the concept of ecosystems. The “previously taught” Get It Or Don’t view conceives of prior knowledge in terms of *if it was taught then it was learned* with little attention to the gradual process of learning and the hybrid concepts that develop as a result of formal and informal learning. In both Get It Or Don’t views, preservice teachers attended only to correct academic language and concepts and not to hybrid ideas or the valuable experience-based concepts that children have developed through many years of interacting in their worlds.

Those coded with the Get It Or Don’t view were responsive to their characterizations of prior knowledge in the sense that they made instructional decisions on the basis of inferences about students’ prior knowledge. The most common examples of this were statements such as, “Because the students expressed no prior knowledge about biomes, I did not change my lesson.” Some teachers did change their lessons when they found that “the students already knew,” the subject; and by “knew” the preservice teachers in this category typically meant that the students were able to articulate the correct academic language associated with the scientific definition of a term. A typical example of the Get It Or Don’t view is provided below.

Example of the Get It Or Don’t View

Rachel was a preservice teacher who had a practicum placement in a fourth-grade class and taught a lesson on *Matter and States of Matter*. In her description of her pre-assessment, Rachel stated the following:

I asked the students: “What is matter?” I was curious as to how they knew what they did because I know that they did not study matter or its states in the particular school system up to the present. I was not really surprised at the results. Because I know that they did not previously study matter or its states their lack of knowledge on the subject was not a shock.

Rachel went on to analyze her data and make an instructional decision quoted below.

According to the graphs and data collected (pre/post), it is evident that the majority of the students do not know what matter is. As I was expecting the students to be unfamiliar with matter when I created my lesson, I did not change or modify my lesson.

This example from Rachel’s work illustrates both the vocabulary and the previously taught Get It Or Don’t views. Rachel assessed students’ knowledge on the basis of the academic terminology “matter,” and concluded that most of the students did not know anything about matter because they were unable to define the term. She then made the instructional decision not to change her lesson, which was designed to help students learn that “matter is anything that has weight and takes up space.”

In most cases of the Get It Or Don’t view, preservice teachers elicited student prior knowledge by using academic language, asking questions such as “What is a *biome*?” “What do you know about *interdependence*?” “What do you think *blubber* is used for?” and “What is a *virus*?” rather than by using the related everyday language such as *needs, weather, plants and animals, fat, and sick*. Pre-assessments that are dependent upon scientific language often resulted in elementary

students responding either that they “did not know” or with their best guess of the meaning of the term. This often led preservice teachers with the Get It Or Don’t view to conclude that their students knew nothing about the topic being assessed.

The Get It Or Don’t view makes clear how preservice teachers’ definitions of *prior knowledge* influenced their enactment of the formative assessment process. If prior knowledge is defined only as academic concepts and language, then academic concepts (often only in the form of academic language) is what is assessed and responded to by the teacher. Although the Get It Or Don’t view does not capture what a student *does* understand about the natural world at a given point in time, it is an important facet of the formative assessment process. At some point a teacher does care whether the students get the objective or intermediate objective he or she is trying to teach. The difference between the Get It Or Don’t and Flexible views is the awareness on the part of the teacher that *prior knowledge* consists of much more than academic concepts and language and that what students *do understand* regarding the topic can serve as resources for further learning regardless of the extent to which this understanding is aligned with academic concepts. Both the EBC and Get It Or Don’t views focus only on one aspect of students’ conceptual framework (*either* EBCs or ACs). The Mixed view, on the other hand, considers both.

The Mixed View

Those coded with the Mixed view elicited students’ EBCs and provided rich descriptions of the types of common and idiosyncratic ideas that represented the class. Like those coded with the EBC view, these preservice teachers appeared to recognize and value students’ prior knowledge. The difference between this view and the Flexible view is in the instructional response. Those coded with the Mixed view did, in fact, respond to their interpretation of students’ prior knowledge but they did not respond to the EBCs and hybrids they had elicited. Instead, they responded to whether or not the EBCs and hybrids they elicited (and carefully described) were fully aligned with the formal, academic concepts that were the objectives of instruction. After describing the EBCs that students had relative to an objective, these preservice teachers made comments such as, “but students did not have any working knowledge of. . .” or “students did not have any scientific knowledge about. . .” These preservice teachers were responsive in the sense that they made instructional decisions on the basis of inferences they made about students’ prior knowledge; however, these inferences were made on the basis of whether the students were able to articulate the full, formal academic concepts or not. If so, these preservice teachers concluded that the lesson was not appropriate, and if not, they concluded that the lesson was appropriate. In other words, these preservice teachers seemed to use an EBC view when *eliciting and describing* students’ prior knowledge and used a Get It Or Don’t view when *responding* to students’ prior knowledge. The Mixed view conceptualizes ACs and EBCs as distinct entities having little or nothing to do with one another. An example is provided below.

Example of the Mixed View

Daniel was a preservice elementary teacher who adapted a lesson and designed a unit on *Lunar Phases* for the fourth-grade students in his practicum classroom. The lesson he would teach was called “Birthday Moons” and the intent of this lesson was for students to generate questions and notice trends about lunar phases, which would motivate subsequent lessons. Daniel’s lesson

plan consisted of students going to the computer lab and using a certain web site⁴ to find the phase of the moon on their birthdays. They would then print pictures of the phases of the moon on their birthdays and everyone would return to the classroom, spread all their birthday moons on the floor, and students would work in groups to notice similarities and differences among their pictures. Daniel hoped that students would notice that there was a finite number of shapes, that sometimes the moon was bright on one side and sometimes on the other side, and that there were more crescent/sliver-type shapes (of various sizes) than there was full bright circles or full dark circles. He anticipated having students try to put their birthday moons in an order that made sense to them. This student-centered activity would lead students to ask questions and offer ideas about how and why these trends occur. This would then be followed by lessons focusing on the role of the sun, earth, light, and seeing, to help explain lunar phases.

For Daniel's pre-assessment, students were asked to draw pictures, provide verbal explanations, and/or write their personal explanations for "why the moon appears to increase and decrease in size throughout the month." Daniel found, among other things, that most of his students did not think that the moon is a source of light. In his summary of his assessment data, Daniel stated,

Of twenty-four students, twenty-two thought that the moon does not give off light like the sun. . . Of the twenty-two who believed the moon glows by different means, only one could offer an explanation.

This statement demonstrates that Daniel was aware that a majority of his class (92%) expressed the idea that the moon is not a source of light. Like those coded with the EBC view, Daniel accessed students' current understandings about the content he wanted to teach. However, as Daniel attempted to respond to his assessment analysis to inform his instruction, he concluded, "Based on my pre-assessment strategy, I knew that my classroom had very little working knowledge about the scientific explanation of things pertaining to the lesson I taught."

The idea that the moon is not a source of light is a first step in understanding lunar phases. It could lead to the question, "If the moon is not a source of light, then where does the light come from?" This type of question builds directly on students' prior knowledge and connects directly to academic objectives involving the role of the sun in the appearance of the moon. When Daniel compared his assessment data to his objectives, he correctly recognized that these students did not express a full academic explanation for lunar phases, but he therefore regarded his students' ideas as "not scientific."

Daniel elicited and described his students' prior knowledge but he did not appear to recognize the value of this prior knowledge for further instruction. Instead, when he compared his findings to his objectives (lunar phases as consisting of relative positions of the earth, moon, and sun, the rotation of the earth, and revolution of the moon) he converted to the Get It Or Don't view based on his conclusion that the data clearly indicated that his students did not have a full, academic understanding of the phases of the moon.

Daniel ended up responding to his conclusion that his "students had very little working knowledge about lunar phases," by making the instructional decision to teach it to them. He overhauled his intended lesson by including a pre-lesson consisting of a didactic introduction to lunar phases, complete with a chalkboard diagram of relative positions, the rotation of the earth, the revolution of the moon, and terms such as gibbous, waxing, waning, crescent, and first quarter as a means for providing the "background knowledge" necessary for the birthday moon lesson (for which he left only 8 minutes to implement). This overload seems somewhat baffling because the lesson he intended to teach was designed to *motivate* further lessons on lunar phases.

Daniel's case represents preservice teachers in this study coded with the Mixed view, all of whom engaged in all parts of the formative assessment process:

- “Where are you now?” These preservice teachers elicited students’ prior knowledge and created rich analytical descriptions of common and idiosyncratic ideas among individuals and the class as a whole.
- “Where are you trying to go?” These preservice teachers stated the objectives associated with their unit or lesson and assessed relevant prior knowledge.
- “How can you get there?” These preservice teachers made instructional decisions or modified their instruction or their objectives on the basis of their interpretations of their students’ prior knowledge.

Although preservice teachers coded with the Mixed view typically demonstrated each of the elements of the formative assessment process, like Daniel, their actions differed from those coded with the flexible formative assessment process described early in this paper. The difference between the Mixed view and the Flexible view is the way in which *prior knowledge* is defined and acted upon. The Mixed view defines prior knowledge as EBCs for the elicitation of students’ ideas and redefines prior knowledge as ACs for making instructional decisions. The Flexible view defines prior knowledge as consisting of ACs, EBCs, and hybrids, all of which are valuable for all aspects of instruction. Teachers who use the Flexible view seek to understand what meanings students have attached both to academic terms and to the world around them and understand that learning is much more than whether the students get it or they don’t. Those that hold the Flexible view understand that the students always get something, and it is the teacher’s job to find out exactly what this is.

Discussion

While the EBC view, the Get It Or Don’t view, and the Mixed view are not fully aligned with the Flexible view of formative assessment, each should be considered as preservice teachers’ conceptual understandings of prior knowledge and formative assessment at a point in time in their teacher education program. Rather than considering these views as misconceptions of the formative assessment process it is more useful to consider them to be hybrid understandings that could be useful for further development of the more flexible concept of formative assessment. Science education researchers have put much effort into trying to understand the conceptual structure of students’ science knowledge. It would be worthwhile for teacher educators to do the same.

The way preservice teachers respond to students when teaching science is closely aligned with the way they view prior knowledge. One generalization that can be made from this study is that these preservice teachers tended to view EBCs and ACs as distinct, serving different purposes in science instruction. The Get It Or Don’t, EBC, and Mixed views approach EBCs and ACs as separate entities having little to do with one another. While Vygotsky also defines EBCs and ACs as having different roots in the cognition of the learner, the theory of concept formation relies on their interaction and co-mediation. According to Vygotsky, the role of schooling is to help students build EBCs toward increased generalization, applicability, and shared language and to help students make meaningful connections between ACs and their own experiences. Therefore, the process of learning relies on the teachers’ recognition of the connection between ACs and EBCs.

The EBC view, the Get It Or Don't view, and the Mixed view all represent aspects of the formative assessment process, yet each isolates one element of conceptual understanding (ACs or EBCs) for either eliciting or responding to students. Teacher educators could respond to these findings by designing activities that use these common views as resources for further development of the concept of formative assessment among preservice teachers. A specific physics curriculum tailored for the preservice elementary teacher population has been developed that translates the research findings presented here into objectives for application activities that focus on increasing awareness and understanding of elementary students' prior knowledge of various concepts in physics (Goldberg, Robinson, & Otero, 2006). This curriculum contains two types of activities: inquiry-based, content-focused activities and Learning about Learning (LAL) activities. In the inquiry-based and LAL activities, preservice teachers investigate the nature of scientific knowledge, they reflect on their own learning of physics within the curriculum, and they then investigate elementary students' learning of physics. The LAL activities that focus on elementary students' learning use short video clips of elementary students as they learn age-appropriate physics concepts. These LAL activities address the Get It Or Don't, EBC, and Mixed views by guiding teachers as they apply their evolving knowledge of physics and of the nature of science toward the recognition of elementary students' ideas as valuable resources for further instruction and learning. LAL activities for the preservice teachers are supplemented with short readings that focus on research about elementary students' common ideas in physics, and help teachers see that while elementary students typically do not use science language, they often do articulate reasonable partial understandings of various physics concepts in their own words.

Like all teachers, teacher educators must be aware of the different types of ideas their students (preservice teachers) express in the formal learning environment in order to tailor relevant instruction. The Get It Or Don't, EBC, and Mixed constructs are useful hybrid understandings of the formative assessment process and should be respected by teacher educators as resources for describing their own understanding and further learning. Teacher educators must also consider possible sources of these views of formative assessment and prior knowledge.

Apprenticeship of Observation

Pre-service teachers have experienced many years of formal instruction. In many ways, this is *their* experience-based knowledge about teaching and learning in schools. These experiences are often associated with traditional measures of achievement which include, and are often limited to, being rewarded for "getting it." Often in science, the right answer on an exam or homework consists of nothing more than a symbol-based or numerical solution to textbook problems. It should not be surprising then, that preservice teachers have come to interpret science learning in terms of vocabulary words, facts, and symbols. Lortie (1975) described *apprenticeship of observation* as the socialization process by which teachers come to understand formal learning and teaching through many years of their own participation as students. If preservice elementary teachers have come to understand the learning of science in terms of getting it or not, rather than in terms of what they do get at a point in time, it is not surprising that even though they appreciate students' experiences, they do not view these experiences as relevant to the instruction of formal science.

Other Teacher Education Courses

Pre-service teachers typically take courses in educational foundations; educational psychology; and reading, writing, social studies, mathematics, and science methods. In these

courses they are exposed to many ways of thinking about teaching and learning that may contradict one another when interpreted by preservice teachers during their process of learning how to teach for understanding. For example, in educational psychology, the term “misconceptions” is often used to describe students’ prior knowledge. The notion of “misconceptions” may be understood by preservice teachers to mean something that is wrong, bad, broken, and in need of being fixed. This could lead teachers to conclude that if students’ ideas are not fully aligned with the academic concept, then these ideas are not useful for further learning and instruction. This notion could be exacerbated if teachers’ views of science are oriented toward science as a set of facts, symbols, and vocabulary.

A method frequently introduced in reading and writing methods courses is the KWL chart. The KWL chart is a chart in which the teacher writes down what students *Know* about a topic, what they *Want* to know about the topic, and after instruction, what they have *Learned* about the topic. Some of the preservice teachers in this study attempted to adapt this method to their science instruction and found themselves eliciting what students knew about the topic and using it not to inform their instruction but only to show students how much they had learned at the end of a pre-prepared lesson. While KWL charts can be very effective for a variety of reasons, this strategy may lead teachers toward an EBC view, where they fail to connect students’ prior knowledge with the actual goals or implementation of a lesson.

Pre-service teachers are also frequently taught methods such as the Word Splash, where vocabulary terms are presented together with a relevant picture, graphic organizer, or scenario. This method is often used in language arts and English language instruction where the goal is indeed for elementary students to recognize strings of characters as words that have very specific meanings. This is one of the first steps in learning how to read or in learning another language. In science, methods such as this may interact with elementary preservice teachers’ notions of science knowledge as a set of facts, figures, and definitions, and therefore may seem like a perfect fit when it comes to helping children learn science. The method itself can be quite effective for its purpose but it can also interfere with understanding and enacting formative assessment as the process of finding out what students *do* know from both prior formal and informal experiences and responding appropriately.

Qualitative Data Analysis Experience

The formative assessment process requires not only that data are collected but also that the teacher is skilled in analyzing these data. In the case of elementary classrooms, assessment data come in the form of pictures, written statements, verbal statements, and student actions. Analyzing such qualitative data requires specific skills associated with recognizing and coding trends in the data for a single student or a group of students. Although both qualitative and quantitative data analysis were specifically addressed in the teacher education course, these skills may take time to develop and implement. Formative assessment requires a complex set of integrated skills associated with content knowledge, pedagogical knowledge, knowledge of students, and data analysis, each of which has to be developed and integrated with the others.

Summary

The results reported here, derived from coding preservice teachers’ written work, provide an initial outline of the types of ideas we might expect preservice teachers to articulate and enact as

they participate in a practicum-based science methods course. These results support four broad claims: (1) preservice teachers come into their science methods courses with some commonality in their views about the nature of students' prior knowledge of scientific concepts; (2) preservice teachers tend to view ACs and EBCs as serving different purposes in science instruction; (3) preservice teachers' views of students' prior knowledge of science may have a significant impact on their assessment practices and therefore on their teaching; and (4) these views should be considered by teacher educators as hybrid conceptions that are a step in the process of understanding the flexible formative assessment model. The EBC, the Get It Or Don't, and the Mixed views represent valuable but incomplete pictures of the formative assessment process. Preservice teachers who learn about formative assessment in their teacher preparation programs bring their own experiences and ideas about how teaching and learning takes place. Understanding what types of ideas preservice teachers bring to, and develop within, teacher preparation programs can help teacher educators make instructional and programmatic decisions about how to help preservice teachers move from where they are to where we want them to be.

Although some (28%) preservice teachers articulated and enacted flexible formative assessment by the end of their science methods course, many did not. However, as shown in Table 2, there was a dramatic decrease in the nonresponsive view (EBC view) from initial to final measures. This may indicate that in one semester, preservice teachers in this study learned that the formative assessment process requires that the teachers respond to the ideas they elicit from their students. The results from this study indicate that while responsiveness is an important objective of science methods instruction, so too is the key question, "To what do I respond?" Science teacher education that responds to this question can greatly facilitate the development of the understanding and enactment of the flexible formative assessment process among preservice teachers.

Notes

¹Vygotsky refers to these two types of concepts as "spontaneous" and "scientific" concepts, respectively. These terms were drawn from Piaget's work on conceptual development.

²The instructor provided written feedback helping Katie learn how to qualitatively analyze her data (pictures and text) in terms of coding it for common occurrences of student idea types.

³Katie adapted a lesson on whale blubber intended to help students feel the difference in temperature of a bath of cold water on their bare hand versus their hand covered with a layer of lard. Students should feel that the lard-covered hand stays warm and the other hand gets very cold.

⁴Daniel used the web site: <http://tycho.usno.navy.mil/vphase.html>.

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Appendix: Example of Written Formative Instructor Feedback

Sara (Pseudonym): Total Score 15/20	Pre and Post-Assessment Plan and Rubric (max. = 8)	Learning and Instruction Part C
<p>Unit Objectives and Standards (max = 4)</p> <p>Your selection of standards is very reasonable. I am always in favor of narrowing it down to just a couple, manageable objectives that can realistically be accomplished.</p> <p>You also did a very nice job stating your personal objectives and how they relate to the standards.</p> <p>You could be more specific about what "bite-sized" chunks you hope to address and how each lesson is designed to address each bite-sized chunk.</p> <p>Nice job integrating with language arts through fiction/non-fiction.</p>	<p>Outlined Unit Plan (max. = 4)</p> <p>Here is what I like about your unit plan: You have taken the care to create time-manageable lessons. So I look at days 7 and 8. In both days you are covering shelter but you have taken the care to discuss "hand and water" on 1 day and "where animals sleep" on another. We often make the mistake of thinking that everything about a particular topic can be covered in 1 day (or realistically, 1 hour). This would give students no time to think, to work, and to reflect. This is just another way that the teacher comes to terms with who she is teaching, why she is teaching and how she is teaching. Sometimes we get these vague ideas of what we want to do and when we start marking down how long it will take, it turns out that it will take 5 hours for what is supposed to be a one hour lesson if we do it right. Super.</p> <p>I think the sequencing is good also and it really gives students time to make knowledge (not just time for you to keep this knowledge). Please keep this type of planning in mind all the time for all subjects.</p>	<p>Detailed Lesson Plan (max. = 4)</p> <p>I assume that your detailed lesson plan is for day 10.</p> <p>I appreciate that you also stated the standard associated with your lesson. This is always such a good idea and it should be clear to anyone who reads it that you address a standard several times throughout the unit.</p> <p>It is always nice to be clear to yourself about exactly what each question in an assessment is getting at.</p> <p>Thank you for your honesty regarding differentiation. On 3/31, differentiation was the subject of our class session. We watched a movie that showed a 4th grade teacher attending to the particular needs of students. We also did activities where I attempted to differentiate according to the needs my students had regarding lesson planning and assessment. You should also be developing a sense of the different students in your practicum and that different students have different needs (some are learning English, some have physical and mental disabilities, students are in different places in conceptual development of particular ideas and skills, some students will need extension activities). The pre-assessment should help you determine more about students conceptually and help you think about how to differentiate.</p>
<p>I think your LESSON pre/post assessment combo is good. For the post assessment you should be sure that gazelles is something with which all students are familiar. In addition, I was wondering whether you might want to provide a picture of the animal and ask an additional question for each animal: "Why do you think so," so that by the end of the unit students should be able to show you that they are relating the structure and function of teeth as important indicators of what animals eat.</p> <p>So if you could make it like: "What do you think skunks eat?" (leave a bunch of space) then needs your objectives, many students should be able to say (or draw) "I think so because it has sharp teeth to chew plants and animals, a deer has flat, blunt teeth and all they can eat is grass." This way you can assess where students are with respect to both of your lesson objectives (omnivore, herbivore, carnivore and teeth). You might also think about assessing students' development of vocabulary. Obviously, it is great if they just get the concepts, but it is nice if they could develop the vocabulary also. Some will go farther than others in conceptual, some will go farther than others in vocabulary. It is good to measure along several dimensions so that you can give all students a chance to be successful.</p> <p>You do not provide a rubric to evaluate your lesson assessment. You will need this when you analyze your assessment data for part D. The dimensions in the rubric should include all of your main objectives and opportunities for students at various levels to receive credit for their current state of understanding of each objective.</p> <p>For the unit assessment you should be careful about asking questions such as: "Have you noticed where prairie dogs live" because a perfectly acceptable answer to such a question is "Yes" or "No." You will need to help students help you know what they are thinking. You might instead ask, "Draw a picture of where you think prairie dogs might live." Why do you think they live in a place like that?" And for question 3, you need to add "why do you think so" otherwise you risk getting fact recall rather than conceptual understanding, what the child is actually thinking. I don't understand the purpose of question 5 (perhaps you are getting at their distinction between fiction and non-fiction). If so, you should help them out a little bit. Help them tell you what they know. For question number 1, what if they answer "cat food," "mice," "birds," what information will this give you regarding your objectives? Depending upon which objective this question is designed to address, you would need to be a bit more specific. For question number 6, once again, students could answer "yes" or "no." This will not help you, as a teacher, learn about your students. You would need to rephrase it in some way even if it is providing several pictures of realistic animals and fictional animals and ask them to circle the ones they think they would find in nature. You could go around and ask them why as they work and take notes in a teacher log as to their understanding of fiction versus non fiction.</p> <p>Pre = 2, Post = 3</p>	<p>Pre and Post-Assessment Plan and Rubric (max. = 8)</p>	<p>Learning and Instruction Part C</p>
<p>3</p>	<p>4</p>	<p>3</p>

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