

**'Flying Blind': An exploration of beginning science teachers' enactment of formative assessment practices**

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### **Abstract**

Despite research indicating the positive impacts of formative assessment on student learning, recent studies have found it is difficult for teachers to enact. This paper presents a conceptual framework for understanding how formative assessment challenges teachers' beliefs, knowledge, and classroom practices. The framework is then used to interpret interview data collected from nine beginning high school science teachers attempting to enact formative assessment after participating in a professional development workshop. Results indicate that beginning teachers are challenged to set learning goals when they are changing schools, courses, and curricula, and become more confident in their ability to do so after multiple years teaching the same course. Teachers were able to develop different types of formative assessments, but once they enacted those assessments they struggled to interpret the information they gathered about student learning. The paper places the findings in the context of professional development for formative assessment and science teacher education.

## Introduction

Formative assessment, or the process by which teachers elicit and act upon student thinking during the course of instruction, is a major priority in science education reform (e.g. National Research Council [NRC], 2001a, 2007). These proposals are strengthened by evidence that shows ongoing formative assessment has a positive effect on student learning (Atkin & Coffey, 2003; Black & Harrison, 2001; Black & Wiliam, 1998). In a more formal sense, formative assessment can be summarized in what has been called the “feedback loop” in formative assessment; that is, setting a learning goal, determining the gap between the learning goal and the student’s present state of understanding, and formulating feedback to close the gap (NRC, 2001a). The feedback loop is illustrated in Figure 1.

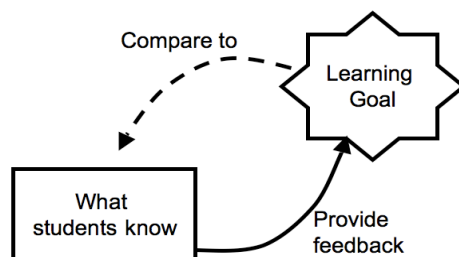


Figure 1. Formative Assessment Feedback Loop

Less formally, formative assessment can be conceived of as the teacher listening and attending to student ideas while instruction is in progress (Sherin & van Es, 2003). Formative assessment can be described as spanning a continuum from the informal, on-the-fly questions a teacher asks to formal, planned assessments or assessments that are embedded in a curriculum (Shavelson et al., 2008).

In a sense, formative assessment can be thought of as creating virtual space in a classroom in which student ideas can be shared with their teacher and peers in a low-risk environment. This process has been conceptualized as teachers holding ‘assessment conversations’ (Duschl & Gitomer, 1997), in which teachers invite students to talk about their ideas, and teachers can give students feedback on the fly.

Although Black & Wiliam’s (1998) meta-analysis found a significant impact of formative assessment on student learning, follow-up studies inspired by their work have found formative assessment difficult to enact in science classrooms (Atkin, Coffey, Moorthy, Sato, & Thibeault, 2005; Furtak et al., 2008). For example, these studies found that teachers need to spend long periods of time learning student ideas and planning formative assessments with the support of colleagues, and even when teachers are able to enact curriculum-embedded assessments, they still struggle to provide timely feedback to move students toward learning goals.

However, if formative assessment poses a challenge to experienced science teachers, it follows that it can be especially daunting for beginning science teachers. This paper explores the multiple levels of challenges faced by nine beginning science teachers in adopting everyday

formative assessment practices.

### Conceptual Framework

A major policy initiative since Black & Wiliam's (1998) finding has been to support teachers in enacting formative assessment in their own classrooms on an ongoing basis. However, despite some encouraging results, recent studies have found that formative assessment is difficult for teachers to enact. For example, an experimental study of the effects of embedded formative assessment on student learning yielded mixed results (Yin et al, 2008), although an implementation study of how teachers used those formative assessments indicated that teachers who were able to provide informational feedback had students with higher learning gains (Furtak et al., 2008). A different experimental study revealed that teachers experienced significant pushback from students when they were provided with informational rather than evaluative feedback (Furtak & Kunter, in press). Results of these studies support the view that formative assessment, while effective when enacted well, is actually an extremely difficult reform for teachers to enact in their own classrooms.

Successful enactment of this practice is dependent upon teachers' beliefs, knowledge, and practice, all of which must be aligned with each step of the formative assessment loop (Figure 1).

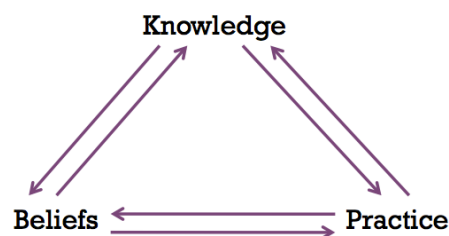


Figure 1. Interrelationship between knowledge, beliefs, and practice in formative assessment

#### Beliefs

In order to successfully enact formative assessment, teachers' beliefs about student learning – as well as their role in that process – must be aligned with the formative assessment process. Unfortunately, this first category of challenge presents a significant hurdle since teachers' beliefs are known to be resistant to change (Kagan, 1992). While teachers' beliefs do not entirely control what they do in the classroom, their beliefs have been shown to be interactive with their practice (Pajares, 1992; Richardson, 1996), so the extent to which teachers buy into the reform-based view of learning upon which formative assessment is based is essential to its successful implementation. Teachers' beliefs must also be consistent with the view that, in order to achieve meaningful learning in the classroom, they must first elicit what students currently know so that they can build upon students' prior ideas and alternative conceptions. Finally, teachers must be able to view themselves as being instrumental in helping students to learn by providing them with informational feedback that will not just tell students whether

they are right or wrong, but will provide the steps that students need to take in order to reach learning goals.

### *Knowledge*

Effective formative assessment is also based upon the depth of teachers' knowledge about the subject, as well as their knowledge about how to teach the subject (Magnusson, Krajcik, & Borko, 1999; Shulman, 1986). This knowledge is domain-specific, meaning that a teacher with a deep background in biology would face significant challenges in conducting formative assessment in a physics unit (Boz & Boz, 2008). In order to effectively set learning goals, teachers need to know common student prior ideas and understand the structure of the discipline they are teaching. To provide feedback, teachers need to know what instructional strategies will help students reach learning goals, including the powerful examples, analogies, and questions that will push students forward in their thinking.

### *Practice*

Finally, teachers' beliefs and knowledge intersect when they enact formative assessment in classrooms. Although beliefs and prior knowledge are related to teachers' practice (Carlsen, 1991, 1993; Pajares, 1992; Richardson, 1996), teachers still must be able to draw upon these resources to make assessment decisions in real-time. For example, sharing learning goals with students at the beginning of lessons can orient students to what they are to learn (Sadler, 1989) and has been shown to be correlated with student learning (Seidel, Rimmele, & Prenzel, 2005). To find out what students currently know, teachers need to be able to draw upon a variety of strategies, especially in the case of asking questions on-the-fly. They also need to be able to identify student ideas when they are shared, and to be able to select and deliver the appropriate feedback to move students toward learning goals.

When brought together, these three facets constitute a framework summarizing the challenges faced by teachers in enacting formative assessment (Table 1).

*Table 1.*

Conceptual framework for challenges faced by teachers enacting formative assessment

	Setting Goals	Finding out what students know	Providing feedback
Beliefs	Buying into reform-based ideas about what science content is most important.	Believing that the teacher must elicit and build upon student thinking to help students learn	Understanding the teacher is responsible for helping students reach learning goals.
Knowledge	Being able to identify the scope and sequence of what students are expected to learn.	Anticipating common student ideas, including alternative conceptions, and knowing what activities will elicit them.	Knowing the compelling examples, analogies, and questions that will help students advance in their thinking.
Practice	Being willing to share learning goals with students to orient them toward what they are going to learn.	Selecting and enacting in advance and on-the-fly strategies to get students to share their thinking.	Being able to identify student ideas and provide feedback to students in a timely fashion.

The framework presented in Table 1 takes apart the steps of the formative assessment loop to identify the beliefs, knowledge, and practice teachers need in order to implement this reform. To set learning goals, teachers must focus on the big ideas of science, content knowledge to help them to identify scope and sequence, and be willing to share those goals with students at the beginning of instruction. They must also believe that they must elicit student thinking and build upon it to help students learn, and have a deep collection of strategies to get students to share those ideas.

Research has indicated, however, that teachers are more likely to believe that formative assessment is important (Daws & Singh, 1996; 1998) and to elicit student thinking (Furtak et al., 2008), but that feedback is less likely to occur in practice. Since Black & Wiliam (1998) determined that it was the third step of providing feedback that has the largest impact on student learning, taking apart the formative assessment process in this manner only draws attention to that fact that it is precisely this step that presents the largest challenges to teachers, challenges that must be surmounted in order to help students learn. Teachers must recognize their own role in scaffolding student learning toward learning goals, must have deep content and pedagogical knowledge to draw upon, and must be able to recognize student thinking and select appropriate feedback strategies for students.

This study seeks to respond to two research questions: What are the challenges faced by

beginning teachers attempting to enact formative assessment in their classrooms, and what do these challenges imply for formative assessment professional development and teacher education?

## **Method**

### *Participants*

Nine high school physical science teachers, eight women and one man, who had participated in a two-day workshop led by the author on formative assessment were interviewed for this study. The teachers are members of a national organization and were thus located at nine different schools in nine different districts across multiple states. The teachers ranged in experience from one to three years, with the majority in their second or third year. All had undergraduate degrees in science and all but one had completed traditional teacher education programs. For the purpose of preserving anonymity of the participants, all teachers are referred to with female pseudonyms.

*Table 2.*  
Background information about participating teachers

Name	Content Background	Content Teaching this year	Content Taught last year	Years Taught	Teacher Ed
Theresa	Geology	Earth Science & Physics	Chemistry	2	MA + Credential
Maria	Physics	Physics	n/a	1	MA + Credential
Rachel	Biomedical Physics	Chemistry	Chemistry	2	PER/Ed Research
Jenny	Geology	Environmental Science	Physical Science	2	MA+ Credential
Carrie	Chemistry & Physics	Chemistry	Chemistry	3	Teacher Residency Program + MA
Emily	Chemistry	Chemistry	Chemistry	2	MA + Credential
Sarah	Chemistry/Math	Physical Science/Chemistry	Physical Science/Chemistry	3	MA (content), Teaching License
Susan	Mechanical Engineering	Physics	Physical Science/Chemistry	2	TFA, earned MA while teaching
Nora	Chemistry	Chemistry	Chemistry	3	Licensure Program

### *Professional Development*

Teachers interviewed in this study participated in a yearlong professional development in which they attended a two-day fall workshop in which they reflected on their current practices and collaboratively developed formative assessments. Then, throughout the school year, they reflected on what they had tried in online discussion boards, responded to each others' posts, received mentorship in the form of comments to the discussion board from a master teacher, and attended a follow-up workshop in the spring in which they shared formative assessments they had tried out in their classrooms.

### *Interview*

A semi structured interview was conducted with each of the nine workshop participants approximately three months following the original fall workshop; the interview protocol is



provided in Appendix A. Interviews were conducted via telephone or iChat, were audio recorded, and then transcribed. Due to a software malfunction during the interview, one teacher's interview audio was partially lost. In this case, I appended interview field notes immediately following the interview from memory to supplement the audio that was saved.

### *Data Analysis*

To facilitate the process of data analysis, interview transcripts were uploaded into Atlas.ti. In a first pass, I attempted to code all transcripts according to the formative assessment enactment framework at the beginning of this paper. However, the formative assessment enactment framework did not easily translate to codes, so during a second pass through the transcripts I created an additional set of codes that emerged from the data (Charmaz, 1983) through an iterative process of reading the transcripts, creating codes, rereading the transcripts, applying new codes and subcodes, and developing propositions. A subset of these codes are shown in Table 3.

*Table 3.*  
Sample of initial codes for transcripts

Code	Description
How students learn	Teachers' description of how their students learn
Purpose of assessment	Description of the purpose of assessment
Type of formative assessment used	Descriptions of types of formative assessment used
What to do with information	Teacher describes struggle to work with information from formative assessment
Major	Undergraduate science major
Years teaching	Years of teaching experience
Courses taught	Courses taught this and last year
Description of self as teacher	Teacher's description of teaching approach
Description of self as learner	Teacher's description of how s/he learns science best
Description of formative assessment	Definition of formative assessment
Easier after teaching multiple times	Reference to how teaching the unit becomes easier each time
Giving feedback	Description to type or strategy for giving feedback
Listening to student ideas	Reference to listening to student ideas for formative assessment purpose
Setting goals	Description of how learning goals are set
Timing	Reference to timing/time pressure

Since this study was less concerned with identifying frequencies than with telling the story of these teachers' experiences, I used these codes to develop insights into the data, and validated these insights through multiple coding passes through the data (Taylor & Bogdan, 1998). Once each transcript had been coded I drew on the coded transcripts to develop a research memo for each teacher focused on formative assessment. Each research memo consisted of propositions about the teacher's use and perceptions of formative assessment, supported by

quotations taken from the coded segments of the transcripts. A sample research memo is shown in Appendix B.

After I had finished all of the research memos, I entered each proposition into an Excel spreadsheet, and then clustered the propositions either by categories in the formative assessment framework, or by emergent categories I noticed when looking across the propositions. Propositions that were not directly related to these categories were left uncoded and did not enter into the final results section of the paper. Examples of these categories are shown in Table 4.

*Table 4.*

Categories used to cluster propositions

Category	Description	Example Coded Propositions
<b>Setting Goals</b>	Sources of and process for setting learning goals	<ul style="list-style-type: none"> <li>• Teacher determines what to assess through pre/formative assessment by considering student misconceptions and what she would want students to know years from now.</li> <li>• Teacher focuses on the big ideas in setting her learning goals.</li> </ul>
<b>Administrative Challenges</b>	Challenges posed by structure of class, schedule, or school	<ul style="list-style-type: none"> <li>• The extent to which students are or are not engaged in the classwork is a primary concern for Teacher</li> <li>• Teacher has 3 preps, which keep her from being where she wants to be as a teacher</li> </ul>
<b>Challenge in giving feedback - knowledge</b>	Challenges teacher faces in knowledge necessary to give feedback	<ul style="list-style-type: none"> <li>• Teacher is unsure of how to handle the information from formative assessment</li> <li>• Teacher struggles to interpret all the information she received through formative assessment</li> </ul>
<b>Challenge in giving feedback - practice</b>	Challenges teacher faces in practice of giving feedback	<ul style="list-style-type: none"> <li>• Teacher is challenged to handle and make decisions on the basis of the data she gets about student learning during formative assessment</li> <li>• Teacher is challenged to get students to take the next steps after they receive feedback of some kind</li> </ul>

<b>Type of formative assessment used</b>	Formal and informal assessment strategies teacher has used in classroom	<ul style="list-style-type: none"> <li>• Teacher is trying out formative assessment in her classroom, primarily through openers and closers and asking students questions in class</li> <li>• Teacher listens to student language and reasoning to find out what students are learning</li> </ul>
<b>Purpose of formative assessment</b>	Teacher's description of the purpose of formative assessment	<ul style="list-style-type: none"> <li>• Teacher views assessment as determining whether or not students have met learning objectives set by her state</li> <li>• Teacher views formative assessment as a way to check to see if students have gotten off track</li> </ul>
<b>View of self as teacher</b>	How teacher describes her approach to science teaching	<ul style="list-style-type: none"> <li>• Teacher describes herself as a guided inquiry teacher</li> <li>• Teacher uses a mixture of traditional an inquiry-based instruction</li> </ul>

Finally, in writing the results of the analysis, I followed Erickson's (1986) process of interweaving general description, particular description, and interpretive commentary. Each section is an interplay between general description (giving an overview of the data and explaining aberrations), particular description in the form of transcript excerpts, and interpretive commentary (interpolated between particular and general descriptions to help the reader focus upon those details that are salient within the frame of the study).

## Results

The following results will be organized by the emergent categories identified when propositions from the research memos were brought together and coded.

### *Description of Self as Teacher*

When asked to describe their approach to science teaching, three of the nine teachers described themselves as inquiry or guided inquiry teachers. As Carrie described it, "I do teach in a guided- inquiry fashion where they're not always doing experiments, but they may have to make sense of some data I give them or find patterns and then like pull ideas together."

In contrast, four of the teachers described themselves as using some kind of mixture between inquiry-based and traditional teaching. For example, Susan stated that she wants to be a student-centered and inquiry-driven teacher, but that "There's times when...it's very

traditional, stand up, teacher talks, students take notes, that kind of stuff.” Similarly, Sarah said that although she tries to use reform-oriented approaches to teaching, her students preferred to learn in a traditional way: “I think I aspire to be very much where students are learning with other students...but I think the reality of my situation, I don’t always hit that.” Maria, who was in her first year of teaching, said that “I want to be able to describe myself as a teacher in an inquiry-based classroom, but I think I’m probably not quite there yet.” The remaining two teachers did not explicitly describe their approaches to science instruction.

### *Purpose of Formative Assessment*

Overall, the teachers described that assessment was a process of finding out what students know. Three of the teachers described formative assessment as being a way to find out of students were meeting state objectives, or to find out what students were ‘retaining’ or if they had ‘gotten off track.’ Theresa focused more on a retention perspective: “I use it a lot to see did they get it, but then do they still have it a week from now. You know, is it something they’re retaining? Do they really understand it?” Similarly, Jenny described formative assessment as. “Like anticipating the process to get from point A to point Z and knowing where students go on that path and how they get off track and having that ready to get them back on.”

Emily, Sarah, and Rachel focused upon changes in their teaching since their first year. Sarah stated that in the beginning she was more focused upon sequencing lessons, or how to introduce labs or lectures. In contrast, during her third year of teaching, Sarah has “Been able to step back more and look at, is my teaching having the desired effect on the students’ learning...because I have some idea of what has worked in the past, and what failed miserably.” Emily too recognized that she had previously made many assumptions about what students knew:

I’ve operated for a long time under the assumption that kids who are coming and actually doing the work that I assign are learning. I had very little evidence of that for a long time...how can I tell if they really are learning?...Last year my focus was really like, ‘Let’s get through the lesson without anything exploding or anyone getting hurt. This year, I really am more interesting in finding out...is anybody getting anything from it...and I realized as I was going through this, ‘Hey, this is formative assessment. I’m asking a question and using student responses to inform my teaching for right this very second.’

In these cases, the teachers recognize that while during their first year they were not ready or able to focus on formative assessment, during their second year they were able to transition to focusing more on finding out and responding to what students know.

### *Setting Goals*

Teachers mentioned that learning goals for their teaching come primarily from state standards and curriculum materials. Two teachers, Nora and Sarah, specifically mentioned that the goals that they have are based on their experiences from previous school years. According to Nora, this means that her learning goals are informed by what her students knew and were able to do

the year before. He said, “The learning goals in the second year came from my experience in the first year, because I knew...what deficiencies my students had.” Similarly, Sarah described her improvement in setting learning goals as follows:

Because of my third, you know, cycle through the material I have some idea of...what it is I want the to be able to do at the end of a unit. I know what students struggled on in the past, and I need to maybe spend more time on, or rethink how they’re getting it. So I feel like I’m able to better make those changes year by year.

Teachers working at new schools and in new content areas or with new curricula felt challenged to set learning goals. As Jenny put it, “As a new teacher teaching a Physical Science/Earth Science combined curriculum in a new school with a new book and students...it’s hard to know where I’m going curriculum wise yet....I don’t know where they’re gonna be confused about and I don’t know what the different levels are.”

Similarly, Rachel said that there was a big difference in her ability to formatively assess in physics, her home content area, versus chemistry, which she was forced to teach at her school. She said that she felt like she was taking “shots in the dark” or “flying blind” in the chemistry course because she didn’t have a good idea of what the students would find hard, but anticipated that when she taught chemistry again, or moved back into her home content area, she would be better prepared to anticipate student ideas as she planned formative assessments.

Two other teachers stated that they drew upon the ‘big ideas’ of science or their knowledge of common student misconceptions in setting goals for which they would then develop formative assessments. Both of these teachers said that they considered what the implications of the content were for students’ daily lives, and focused on lasting understandings that students would remember long after taking the course.

#### *Type of Formative Assessment Used*

All of the nine teachers described themselves as enacting some kind of formative assessment three months after the professional development workshop. However, the type of formative assessments the teachers were using varied from formal to informal formative assessment, and some teachers mentioned that they were using formative assessment more than others.

In terms of formal formative assessment, the most commonly mentioned approach was the Predict-Observe-Explain (POE) assessment (White & Gunstone, 1991), which is perhaps unsurprising since these were physical science teachers and the POE can be used as an adaptation of classroom demonstrations. Six teachers explicitly mentioned that they used POE’s, or gave examples of POE’s they had developed. One of the teachers, Sarah, described how one of her POE’s grew out of her experience with students in the class:

I had done a short activity with...a tabletop cloth trick...it was just a jar on a

piece of paper. I pulled the piece of paper out and I didn't move it. Students weren't ultimately surprised because they had seen the tablecloth trick...so a couple of days later I did the exact same demonstration but I did sort of a predict-observe, explain with a toy truck instead. And the truck didn't move. And so many of my students predicted it would because of the tires, because they would move, you know, it could spin and whatever and that was different from the jar that didn't have tires.

In this case, Sarah built on what she had noticed about what was not surprising to students about the jar and paper demonstration to design a POE that challenged students on a deeper level. She was surprised that, although most of her students could predict what would happen to the jar, at least a quarter of them did not understand why the truck did not move. Thus, Sarah was able to get additional information from her students by designing her own POE.

Another teacher, Carrie, modified the POE format to formally incorporate another explanation phase, and she constructed formative assessments on this model. She referred to this as a PEOE. As a chemistry teacher, Carrie took the opportunity to draw on what students had learned about molecular structures and smells to predict the smell of molecules they had not yet looked at. She said,

They made their prediction, and then they had to explain well, why? And so...students in their explanations in class when they shared, some of them brought that they thought maybe...it just smelled the same because they have the same molecular formula. But other students explained, well, that the names are different, so maybe something's going on with that.

Two other teachers also described POE's they had developed, Rachel about limiting reagents, and Nora about kinetic molecular theory. Nora said,

We're gonna do a POE on diffusion and condensation and evaporation, just to get kind of ideas of – what are my students thinking when, for instance, - if I take a drop of food coloring in cold water versus hot water, what's gonna happen, and why? And then get kind of ideas of what they're thinking and then what they know about, I guess, kinetic molecular theory and just how molecules move and stuff like that.

In each of these cases, these beginning teachers were able to draw on what they knew about their students to develop specific, formal formative assessment prompts. In contrast, another group of teachers relied upon less formal formative assessment strategies. A common approach among the group was the use of 'in' and 'out' questions, or 'exit tickets', where students would respond to some question related to the lesson for the day at the beginning or end of class, or both. Although some teachers used both POE's or more formal prompts in addition to in and out questions, two teachers used this type of question almost exclusively for written formative assessment. For example, Theresa said that "I start every day with an opener, and I ultimately

like to end every day with a closer, a closer question that kind wraps it all up and then we can have a short little discussion before we end the class.”

Similarly, Jenny said,

I ended up doing over the last two years an in and out question each day to get a sense for what students knew. It became more of a review. And I’m not sure exactly where the line between review and formative assessment is – I think it depends on how you use it...so an in question might be, you know, some factual question about what we talked about yesterday or a question that they wouldn’t necessarily know the answer to, but I wanted to see what they already knew.

In the case of Theresa and Jenny, formative assessment was embedded in the daily cycle of a lesson. Both Theresa and Jenny referred to the questions being a type of review, however, distinguishing their use of these questions somewhat from the POE’s developed by some of their peers, which were more clearly growing out of student questions and confusions.

In fact, an important difference within the group was that some teachers seemed to be more able to create their own assessments, whereas others relied more on informal questioning, in and out questions, or prompts they found in other sources. Jenny mentioned using prompts from Paige Keeley’s book (2008), and Emily looked at student responses to classwork and homework to find out what students knew.

Most of the teachers also talked about the process of listening to student ideas as an important element for formative assessment. Susan, for example, used formative assessment as a way to have students make their thinking explicit:

I also just really, as much as possible, try to create opportunities for students to explain things in their own words, whether it’s like how to solve a problem or why something happens out loud. So I think there’s a lot of verbal assessment.

Similarly, Sarah described how she listened to student language and reasoning to find out what they were learning, stating “I’m constantly asking them to, you know, explain what you did, or how you came to this conclusion or something like that. So I can look more into the reasoning that went behind something they told me rather than just looking at an end answer.” However, several teachers recognized that asking questions was not necessarily enough to get an impression of what all students thought. As Theresa put it, “When you’re doing that question-and-answer thing, especially with me, one of my bad things is that it ends up being – it’s a discussion between me and whoever’s participating.”

Thus, the beginning teachers are trying out a variety of formative assessment approaches, ranging from informal questioning and review of student work, to in and out questions and Predict-Observe-Explain assessments. Although a majority of the teachers were developing their own POE’s, three of the teachers did not develop their own assessments beyond writing

daily in and out questions or reviewing classroom. Even in the minds of two of these teachers, it was not clear that these in and out questions served a formative, rather than review, purpose. In one case, Maria – who used both in and out questions as well as POE's - made a distinction between what she called "content-based" questions

...like 'solve this problem' and then we go over it. The ones that I think are more interesting formative-assessment-wise are when I ask kinds like what, to you, what is the meaning of this work at this point in your physics education? Do you really understand what momentum means? Or things like, 'what is your goal by the end of this unit? What do you still need to learn?'

In light of this interpretation, it is possible that these two teachers were conducting less formative assessment because of the format that they were using to collect information about student learning.

### *Challenges to Giving Feedback*

Eight of the nine teachers explicitly described challenges to giving students feedback in the course of formative assessment. These challenges corresponded with the knowledge and practice dimensions on the formative assessment framework in this paper. In terms of knowledge, one teacher described being unsure of how to interpret the information they collected from formative assessment, and with respect to practice, five of the nine teachers described challenges with actually giving that feedback to students.

Although most teachers did not mention having trouble drawing on their content knowledge to interpret student ideas as a basis to provide feedback, Jenny did mention that once she had collected a number of student responses, she wasn't sure "about my skills or knowledge as a teacher...how do I look at it? How do I make decisions from it?"

The seven other teachers that mentioned challenges to their practice in terms of providing feedback to students struggled with what instructional action to take given a particular set of student responses. Several teachers described feeling overwhelmed by the information they had collected. Sarah vividly described her experience one day:

I think that's where I'm really feeling frustrated...what do I do with that information now, because they're telling me they don't understand? But if I wouldn't have asked that, I would have never known, I think I just stared at those for – I had them on my desk and I'm like, okay now what? What do I do now that I know they still feel like they don't really know?

Both Susan and Emily described skepticism at providing students with written feedback on their work. According to Susan,

I read something and then I write comments on it. But I'm not really sure that that's the most effective way to do it, and then when I do give them comments



I'm not really sure if they're going to read them. And if they're not going to read them how do they get that feedback?

Several teachers thought about the kind of instruction that might come after a formative assessment. Nora, for example, said, "Where do we go from the data that I get from that? How do I use that? ...Do I give another POE, or do I give that on a test and see if they can – what they draw a picture or what they describe on paper or something like that?" Rachel similarly stated that it was a "hard call" as to what kind of instruction is best to do when they don't get it. In all of these instances, the teachers mentioned that they wanted specific instructional strategies for giving feedback to students.

When speaking of this challenge, several teachers also mentioned time pressure at their schools to keep moving to cover the curriculum. According to Carrie,

Well, because, quite honestly, just to stay on schedule is one big thing. In terms of – it's the age-old question of like when do you move on? And sometimes I give myself some flex time and I might have a day built into my schedule so we can kind of like float things a little bit, but usually it – I kind of have things planned out pretty far in advance.

Similarly, Maria said,

I think my biggest challenge is knowing when the feedback I get from my kids tells me that we need to stop for a while and really fix what is not working and when I can sort of go on...I really want to spend three more days on this, and then I'm also feeling pressure from the [state test] like my kids are going to be tested on every single one of these concepts in June so I gotta go.

#### *Challenges in Course Load and Content Area*

In addition to the challenges listed above, teachers also cited a variety of other managerial and administrative challenges that made enacting formative assessment difficult for them. For example, Sarah teaches at a small school and has four preps, which she feels is keeping her from developing as a teacher. She said, "I feel like sometimes having to prepare for four different classes...I feel pulled I guess I different – too many different directions...so I feel like it's almost like a teeter-totter that I don't feel like all four of my classes are up at that point at the same time." In this case, having to prepare for multiple classes is keeping Sarah from teaching the way that she wants to. As stated above, teachers like Rachel and Theresa who were teaching outside their home content area echoed the impression that their ability to plan, anticipate student ideas, and conduct formative assessment was compromised. Jenny also felt challenged by working with a new curriculum at a new school.

#### **Discussion**

Although the preceding results indicate that the majority of teachers in the study had beliefs about teaching and learning consistent with formative assessment, they were challenged in

terms of the knowledge and strategies they needed in order to realize it in their classrooms. Results of coding the interviews with these nine beginning teachers suggest that, at least for this audience of teachers, beliefs were not as much a challenge to enactment of formative assessment as were knowledge and practice. I revisit the three formative assessment categories of the framework in the sections below, focusing on beliefs, knowledge, and practice in each.

### *Setting Learning Goals*

Although the teachers in this study all had in-depth content preparation in the physical sciences, many of the teachers expressed that it was more difficult to conduct formative assessment in the courses outside their content areas. As Rachel described it, she felt like she was taking “shots in the dark” or “flying blind” when she conducted formative assessment in her chemistry class, because she didn’t know where students would struggle. In contrast, based on her background in physics, she was more familiar with what would be challenging to students and how to support their learning. Similarly, several teachers explained that their ability to teach was improving as their experience with the unit and content deepened over time. This finding suggests that switching teachers between different preps or between different curricula could compromise their ability to conduct formative assessment.

### *Finding Out What Students Know*

All of the teachers had used some kind of formative assessment in their classrooms in the three months since the workshop. Of the formal formative assessment strategies teachers created, most used POE assessments, many used ‘in’ and ‘out’ questions, and most described the process of informally listening to student ideas. The teachers who used POE’s created them as adaptations of the demonstrations they already used in their instruction, or in response to their students’ questions or ideas. In contrast, teachers who used ‘in’ and ‘out’ questions seemed to use them more as a review rather than an opportunity to find out student ideas.

### *Providing Feedback*

The largest concern overall of these teachers was the challenge faced in giving feedback to students. This result suggests that teachers found it much simpler to create opportunities for students to share their ideas than it was to determine what to do with that information once they had it. Teachers struggled not only with how to interpret ideas, but how to make the decision to move on or to re-teach given time constraints. They wondered about the utility of providing feedback in writing, as well as the best instructional strategies to help students move toward learning goals.

### *Implications for Professional Development in Science Education*

The practice of formative assessment, as illustrated by the teachers in this study, is incumbent upon teachers’ knowledge of and experience with a particular content and curriculum. This finding highlights the danger of preparing teachers for formative assessment in a content-free environment. While generic formative assessment strategies are certainly useful to help teachers consider new approaches to finding out what students know, ultimately their ability to develop high-quality formative assessments linked to their students’ knowledge is dependent upon teachers’ own knowledge of the content, as well as their ability to come up with feedback

strategies tailored to the students' ideas.

In addition, the study highlights the importance of helping teachers to learn specific feedback strategies as part of formative assessment professional development. As the experiences of the teachers in this study illustrate, learning how to develop formative assessments alone is not sufficient to help them respond to student ideas.

### *Implications for Science Teacher Education*

This paper presents an argument for why research studies seeking to engage teachers in the process of formative assessment have run into hurdles: the reform is hard to achieve because it is incumbent upon teachers' knowledge and practices, which vary across subject areas and develop through years of experience. Teacher educators, administrators, and policymakers may use the conceptual framework presented in this paper to support beginning teachers in enacting formative assessment practices.

For example, teacher candidates should be supported to develop formative assessment for specific content units, rather than speaking about it in general terms. In this way, teacher candidates can learn about resources for setting learning goals, such as the National Science Digital Library, where common student misconceptions are listed. Similarly, teacher candidates can receive help during teacher education in anticipating the kinds of student responses they might receive to their formative assessments so that they can consider feedback strategies in advance.

In addition, administrators should support beginning teachers in developing the knowledge necessary to plan for and conduct formative assessment by creating manageable workloads and schedules for them. For example, this would mean allowing new teachers to teach the same courses for multiple school years, to use the same curriculum, and to teach a limited number of courses at a time to focus their energy on learning one set of concepts and common misconceptions.

Future research should explore the abilities of teachers to enact formative assessment practices in their home and new content areas in order to better understand the extent to which these practices are transferable. Such a study would draw primarily upon classroom data, rather than interviews, to better determine the extent to which teachers' familiarity with the content – some would say their pedagogical content knowledge (Shulman, 1986) – interacts with their abilities to formatively assess students.

In addition, researchers could also focus upon the extent to which teachers' beliefs about assessment interact with their ability to enact it in the classroom. Although exploring teachers' beliefs about assessment was aim of this study, the interview data I collected did not yield sufficient information to make claims about the interaction of beliefs and ability to conduct formative assessment. Future interview protocols should focus more explicitly on this area.

Given the current push in educational research to study the impact of formative assessment, this paper provides a new conceptual framework for framing the challenges teachers face when enacting this reform, as well as data illustrating these challenges in the first years of teaching practice. It may not be possible to prevent teachers – whether novice or expert – from ‘flying blind’ when they are teaching in a new content area, but the results of this study help to highlight some of the needs of teachers to help them develop the knowledge and practices necessary to become better formative assessors.

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## Appendix A: Interview Protocol

### **General Questions**

1. What courses are you teaching this school year?
2. How long have you been teaching those courses?
3. How long have you been teaching at [school]?
4. How long have you been teaching overall?
5. What did you study as an undergraduate [what discipline of science, mathematics, etc.]?
6. Tell me about your teacher preparation program.
7. What kinds of courses did you have that were specific to science teaching?
8. What are some of the things you learned about?
9. Do those apply in your teaching today? Why/why not?
10. How would you describe yourself as a classroom teacher?
11. How do you learn science best?
12. How do you believe your students learn science best?

### **Questions about Formative Assessment**

1. How do you know when learning is occurring during an everyday science lesson?
2. What, to you, is the purpose of assessment?
3. What does the phrase 'formative assessment' mean to you?
4. How do you set learning goals for your students?
5. What does the phrase 'feedback' mean to you?
6. Now I'd like you to talk freely about what you have done in your own classroom with regard to formative assessment.
  - a. What kinds of formative assessment activities were you doing before participating in this professional development?
  - b. Since participating in this professional development, what activities have you tried in your classroom that you would consider to be formative assessment?
  - c. How did those activities go?
  - d. What did you find out about student learning?
  - e. Based on your experiences, what would you like to try next time?
7. What could we have done in the professional development session that would have better prepared you to use formative assessment in your classroom?

## Appendix B: Sample Research Memo Excerpt

### *Research Memo - Maria*

#### **Proposition 1: Maria uses a variety of informal formative assessment approaches.**

It varies from day to day, so sometimes I'm basing my judgments on whether they met the objectives based on student comments. Sometimes I'm basing it on - at the end of class \_\_\_\_\_ working through some problems and I wander around looking at people's papers and say, "Okay, are they getting the setup? Are they drawing the picture correctly? Are they using the right formula? Do they know what 'acceleration' really means? Are they picking out the information?" Other times it's more concrete. Sometimes I have a ticket at the door - not as often as I would like to, but I've done that occasionally, and that's really helpful because sometimes they're answer-a-question sort of tickets at the door and other times I do like, "What are you still confused about?" or "What did you learn today?" so I can get different kinds of information from that. Another thing I like to do is - sorry, one more thing - have them try to self-assess, and I don't know how valid this is because their judgments of how confident they are may not accurately reflect how well they actually understand, but I just have them hold up their fingers like, "Zero through five, how confident are you in applying this idea?"

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In my mind, formative assessment is about checking along the way how the kids are doing, so it can be a whole bunch of different things. I'm sort of torn about whether a quiz can be a formative assessment or because I feel like when I give a quiz, I expect them to already know the information, and I think of formative assessment as usually less formal and probably not graded, but at the same time, quizzes are sort of along the way to the test, and they do give me information about where we need to go next.

#### **Proposition 2: Maria views feedback as something she gives to students, although not so much on informal as on formal assessments.**

That's something I'm trying to work on this year. I don't think for some of the informal things I've described, like holding up fingers and tickets at the door and stuff, I don't know that I do give my students a lot of feedback. I think I'm better at giving feedback when there's a paper involved, like there's a quiz I'll score, and sometimes I write suggestions, and then on most quizzes, my students do corrections, so they look at the quiz again, then they can ask for help and we go through it and make sure that they're getting what they need to so that they - when I give back the score, they have some feedback about how well they did, and then they can try again. Sometimes I give more general feedback, like I'll pick out a place where I can see people are getting confused from looking at the homework or we do something called whiteboarding a lot where we - the students will write up their solution to a problem and then they'll present it very briefly to the class, and then sometimes other students will do this, sometimes I'll do this, is point out some common pitfalls that other people may have had, or sometimes there are errors on the board so we can talk about how to make that better and why that mistake was made.

#### **Proposition 3: Maria also uses more formal formative assessment strategies.**

We do something called whiteboarding a lot where we - the students will write up their solution to a problem and then they'll present it very briefly to the class, and then sometimes other students will do this, sometimes I'll do this, is point out some common pitfalls that other people may have had, or sometimes there are errors on the board so we can talk about how to make that better and why that mistake was made. One of the things I do most often is predict-observe-explain, and I heard about this actually in my student teaching placement in middle school that did this a lot with demonstrations, and I like the structure where the - 'cause I get the kids' previous ideas out there, which doesn't always happen if I'm not thinking about how to structure a demonstration, like they have to tell me what they think - what they think will happen, and they have to write it down so they're committed to something, and then they can see, "Oh, well," either "yeah, I understood that. I totally understand this concept" or "wait, clearly something was missing. What's going on? I don't get it."

So I like those a lot, and then when I - we talk about 'em usually and then they'll hand 'em in and I can read them in a little bit more detail, but I don't look at every single one 'cause the themes are pretty common once you look at like 20.