

Growth in STEM Teachers' Formative Assessment Practices as Teachers Remain in High-Need Districts

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Abstract

The way teachers design activities and interact with students during instruction directly impacts students' opportunities to learn (OTL). Previous research has shown the merits of formative assessment (FA) in supporting students' active sense-making, leading to improved student success outcomes. We examined 22 STEM teachers' classroom videos, performing FA in class, taken from two different years of teaching in high-need districts. We then coded the videos according to two basic teaching moves - eliciting information about students' thinking or advanced learning. These moves can also be categorized as more authoritative (univocal) class discourse or more dialogic (multivocal). Our results show that thirteen out of the twenty-two teachers in this study diversified their teaching moves over time as they gained experience while persisting in high-need districts. The results also suggest five different teachers' clusters, representing different changes over time in these teachers' teaching moves. Teachers' reflections on challenges they faced while teaching and changes in their assessment practices over time suggest that changes in their teaching purposes resulted in shifting their teaching moves. These shifts supported their students' different challenges, building meaningful relationships with their students, and allowing them more OTL.

Background

The new *Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013) advocate a shift from teaching science as isolated disciplinary subjects to a combination of disciplinary core ideas, crosscutting concepts, and practices. This framework aims to provide opportunities for students to become active learners and connect science taught in the classroom to their daily lives. Likewise, in mathematics, Common Core's vision focuses on teaching mathematical processes contrary to traditional algorithmic teaching (Koestler, Felton-Koestler, Bieda, & Otten, 2013). Decisions about teaching science and math as ways of thinking vs. instruction of content knowledge depend largely on individual teachers' choices about assessing. Research in past decades has focused on formative assessment (FA) merits in supporting students' active sense-making, leading to improved student success outcomes. Therefore FA has become an increased practice of many skilled teachers (Black & Wiliam, 1998; Ruiz-Primo & Furtak, 2007). Moreover, the way teachers design a FA and interact with students through assignments, activities, and feedback affects students' attitudes (Brookhart, 1997; Ruiz-Primo, Furtak, Ayala, Yin, & Shavelson, 2010), students' learning and understanding (Ruiz-Primo & Furtak, 2007), set the main goal for the lesson (Stiggins & Conklin, 1992), and provide students different levels of opportunities to learn (OTL) which support particular forms of students' cognitive engagement (Gresalfi et al., 2012; Hiebert, 1997). Kang et al. (2016) contend that students' OTL are a direct product of both design and instruction. Moreover, they suggest that OTL result from a "sequence of coordinated events," beginning from planning high quality and engaging tasks that provide students with more opportunities to learn and then provide support in class. Sociocultural theorists view learning as a complex organization with multiple components that

combine to create the conditions that allow students to participate in the classroom community and not just a process that occurs in one's brain. (Greeno & Gresalfi, 2008, Kang, in press). Any encounter between a teacher and students generates multiple intellectual, relational, and linguistic challenges derived from the interaction of different life histories, points of view, and cultural practices. As a significant component of this organization, the teacher can affect students' OTL by addressing these different challenges, especially for students from non-dominant backgrounds (Kang, in press). However, what influences the teacher's responses and moves in class? From a sociocultural perspective, teachers' moves are viewed as a response to a situation, including nonresponding (Greeno & Gresalfi, 2008; Kang, in press). Teachers are always engaged in a cyclic process of noticing students' discourse and behaviors, interpreting these, and responding. As a response to what they noticed and interpreted, teachers' moves can either elicit information about students' thoughts and ideas or advance students' thinking towards a scientific principle or an idea. These moves can also be categorized as a more authoritative class discourse, a univocal view of the scientific perspective, or more dialogic, a multivocal view allowing more than one perspective to actively participate in the class discourse (Dini et al., 2019). Teachers can switch between different moves and class discourses to support different teaching purposes at given points in the lesson (Aguiar, Mortimer, & Scott, 2010). Since teachers' roles and beliefs change over time and with experience, we aim to investigate how their teaching moves change over time in response to their noticing and interpreting students' thoughts and behaviors and what are the students' challenges they attend with these moves. We consider that STEM teachers who persist in teaching in high-need districts are evolving, becoming more effective in teaching and can use a wider variety of teaching moves. Therefore we aim to characterize teachers' effectiveness by understanding the development of their assessment practices.

Research Questions

This study is part of a larger longitudinal project that focuses on K-12 STEM teachers' effectiveness who have persisted in teaching in high-need school districts. This research asks:

1. How do K-12 STEM teachers' assessment practices change from when they began teaching in a high-need district?
2. How do K-12 STEM teachers' diversity of teaching moves and classroom discourse change over time?
3. In what ways do K-12 STEM teachers become more effective as they become more experienced in teaching in high-need districts?

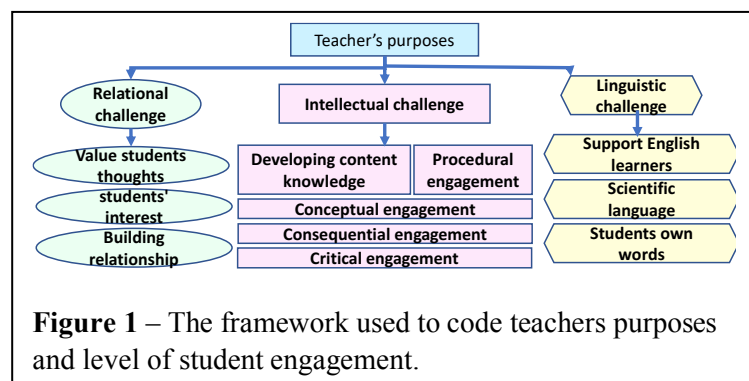
Methods

Data for this study were collected during one year from each of 22 STEM teachers in elementary (2), middle (7), and high schools (13) on the East Coast of the United States. The elementary school teachers were both math teachers, the middle school teachers taught math (3) and general science (4), and the high school teachers taught chemistry (5), biology (4), physics (2), and math (2). Their teaching experience varied between 3 to 20 years, with a mean of eight years. We also collected a broad range of data from an earlier year in each teacher's career. Therefore, we had data from two different years in their careers ranging from 2 to 9 years apart for each teacher. The dataset included (1) video observation from an early stage of career; (2) video observations from two different teaching units in the year as the current stage of career observations; (3) video artifacts that include a blank copy of the FA, copies of deidentified student classwork from the FA, audio recordings

from the consented students discussing in groups, and teacher's self-reflection about the FA; (4) teacher's comments on selected video clips; and (5) an interview that investigated challenges the teachers face while teaching, in which they reflected on changes in their assessment practices over their career and why they made those shifts. The teachers who participated in this study designed or adopted the FA activities themselves as part of their daily teaching and chose which FA activity to record and share with us.

This study uses an exploratory sequential mixed method, characterized by an initial qualitative data collection and analysis, followed by quantitative analysis. Finally, it integrates the two methods to provide a more in-depth understanding of the teachers' effectiveness.

Guided by our analytical framework, the FA enactment model (Dini et al., 2019), we divided all videos into meaningful episodes and coded each episode holistically, meaning coding the episode as a whole. We coded for the two basic teaching moves used by teachers. The teacher can *elicit* information about students' ideas or *advance* learning. Eliciting moves can be either *narrow (authoritative)* towards something the teacher wants to know (e.g., answer for a specific question) or *open (dialogic)*, giving students opportunities to express diverse arguments (e.g., asking for students to discuss different explanations). Advancing moves can be either *directive (authoritative)*, guiding students towards a specific idea (e.g., move students towards the teacher's line of reasoning) or *responsive (dialogic)*, giving students opportunities to argue, debate, and reflect their own thinking (e.g., rebroadcast a student idea to others to debate). Next, to simplify our data set to help us identify different characteristics hidden in the full dataset, we chose hierarchical cluster analysis as the classification technique that groups different objects according to their similarities regarding a specific variable (Everitt et al., 2011). We then consulted the dendrogram to determine the number of clusters in the data. Our choice of this method was because we did not have a priori knowledge about the number of clusters in the data. Last, according to the sociocultural perspective guiding this study, teachers affect students' OTL by addressing different student's challenges. We used a framework that combines Kang's (in press) coding scheme for students' challenges with the four levels of student engagement of Gresalfi et. al (2012) to code teachers' purposes while designing tasks (see figure1). We aimed to find out if their purposes of



addressing different students' challenges have changed over time. Teacher purposes were coded for all the challenges they addressed. In the coding scheme under the relational and linguistic challenges, there are examples of how the teachers engaged in addressing the challenges (e.g., building relationships with the students to address the relational challenge). Under the intellectual challenge are the different

engagement levels the teacher expects students to take while designing tasks. A procedural engagement (lowest engagement) asks students to follow directions (e.g., plunge numbers into a formula). A conceptual engagement asks students to think about the meaning (e.g., understanding the formula used). A consequential engagement is asking students to connect an impact to action (e.g., what low pH means). A critical engagement requires the highest level of student engagement by making a deliberate choice of which tool to use to solve a problem (e.g., students are expected

to choose the tool to explain why a moving object stopped). We also found the need to add another lower level of engagement called "Developing content knowledge", which focuses on teaching or recalling content knowledge without explaining its implications.

Findings

Teachers' diversity in teaching moves

To address our three research questions, we coded 546 teaching episodes. First, we were interested to see if teachers diversify their teaching moves over time, meaning they became more effective

Table 1 – Prevalence of teaching moves among representative teachers (each row is one teacher). The first one increased her diversity when comparing the current video to the early stage of career video, the second did not change and the third decreased in teaching diversity.

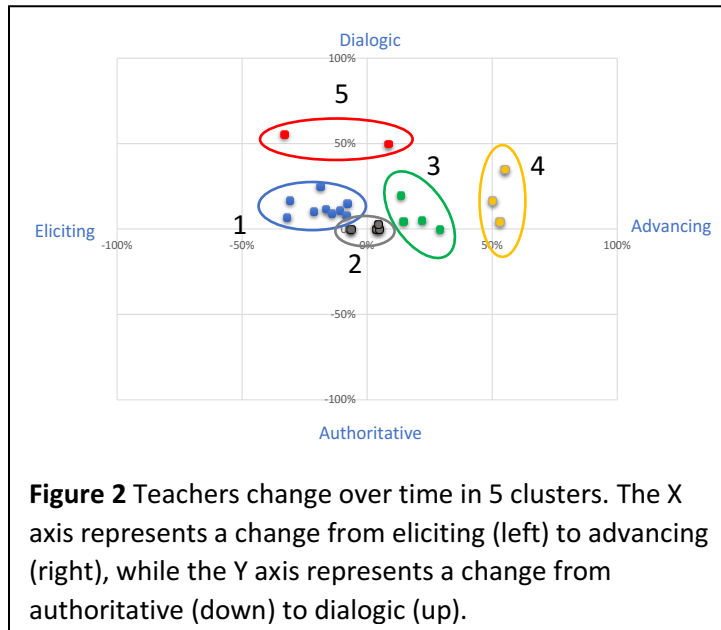
Teacher	Early				Current			
	Narrow Eliciting	Directive Advancing	Open Eliciting	Responsive Advancing	Narrow Eliciting	Directive Advancing	Open Eliciting	Responsive Advancing
Diversity of teaching moves increased	0%	100%	0%	0%	14%	69%	17%	0%
Diversity of teaching moves did not changed	33%	67%	0%	0%	40%	60%	0%	0%
Diversity of teaching moves decreased	27%	73%	0%	0%	0%	95%	5%	0%

in using a broader set of teaching moves for their purposes (see table 1 for representations). Our results suggest that thirteen out of the twenty-two teachers increased the variety of teaching moves in their current careers compared to their earlier career video. For example, teacher HSM2, who used only directive advancing moves in the early FA and then used narrow eliciting (coded in 14% of the episodes), directive advancing (69%), and open eliciting (17%) in the more recent FA. Five of the teachers did not change their variety of teaching moves. For example, teacher HSB2 used the same two teaching moves in both stages and in similar prevalence. Four of the teachers have decreased in their variety of teaching moves. For example, MSG3 used directive advancing teaching moves in 95% of the episodes coded. Overall, results show that most teachers in this study use a wider variety of teaching moves, as they gained more teaching experience.

Five different clusters of change within time in teaching moves

The cluster analysis resulted in a five-cluster solution, as shown in figure 2. Figure 2 also shows that none of the teachers became more authoritative over time, represented by all Y-axis values equal to or greater than zero. Lastly, we coded the teachers' purposes, as reflected upon in their interviews.

1. Cluster 1 is the teachers who are now practicing more eliciting moves than they did earlier in their careers. All teachers in this cluster increased the level of engagement they expect from their students (intellectual challenge). They also added dealing with the relational challenge to their purposes, stating that they now value students' answers more than the past and emphasize a class culture that focuses on students sharing their ideas. For example, teacher HSC3 increased the expected engagement level from conceptual to both conceptual and consequential levels. HSC3 also added relational purposes, stating that she now values students' thinking more than before and is interested in building meaningful relationships with her students based on trust. HSC3



mentioned that as a young teacher, her mentor encouraged her to record who is right or wrong. Today, she publicly encourages them to speak out without fearing that their answers are wrong and asks students to take ownership of their learning.

2. Cluster 2 are teachers who did not change their teaching moves nor their class discourse over time. These teachers ask for the same engagement level from students and state they became better at improving grades and assessing content knowledge. For example, teacher HSB2 stated that her questioning type did not change from the beginning of her career, focusing on

assessing content and procedure (both requiring a low level of engagement). HSB2 also mentioned that she is impatient with students' answers and prefers to explain by herself.

3. Cluster 3 are teachers who are advancing more than they used in the past. These teachers changed their intellectual purposes, encouraging a higher level of engagement from their students, also addressing students' relational challenges, and valuing students' thoughts. However, the teachers in this cluster all stated that they are content knowledge and standardized test-oriented, looking for misconceptions, and improving the quality of students' answers. For example, teacher ESM1 is now requiring procedural, conceptual, and consequential engagements after asking for only procedural engagement earlier in her career. She mentioned she became an expert in understanding students' misconceptions and guiding them to "better" answer questions. She also added relational purposes, designing assessments to be meaningful for the students. It is also worth mentioning that 3 of the 4 teachers in this cluster decreased in the variety of teaching moves, using more directive advancing than earlier in their career.

4. Cluster 4 switched to mainly advancing their students. These teachers engage their students at a much higher level than before and are very invested in their students' relational challenges allowing them more OTL. They differ from cluster 3 because they focus on improving understanding and thinking rather than improving knowledge and grades. For example, teacher HSC6 switched from developing content knowledge to asking students to engage in conceptual, consequential, and critical levels. She also started to address relational challenges and focus on building relationships with her students based on trust.

5. Cluster 5 switched to being mainly dialogic while emphasizing relational challenges, valuing students' thinking. For example, HSP1, a teacher with 20 years of experience, did not change her intellectual engagement demands from earlier in her career but decided to stop asking students narrow questions and started to ask students to share their thinking, with the intention of making her students more comfortable to share assumptions.

Summary and Discussion

Our results show that most teachers in this study diversified their teaching moves over time as they gained experience while persisting in teaching in high-need districts. The results also indicate that a change in teachers' purposes could explain the change in teaching moves. It is well documented that the way the teacher frames the activity directly impacts the way students are likely to engage it (Henningsen & Stein, 1997; Kang et al., 2016; Stein et al., 2009). That means that when teachers increase the level of engagement in their tasks, they need to change their teaching moves to support it, and they allow students more opportunities to learn and engage at a higher level than before (Gresalfi, 2009; Gresalfi et al., 2012). Seventeen out of the twenty-two teachers in this study switched their class discourse to be more dialogic. Moreover, most teachers stated that they had increased their focus on relational challenges, now valuing their students' thinking more and building meaningful relationships with them. Previous research shows that building relationships with students gives teachers access to students' identity, promotes equity, and improves students' learning opportunities (Kang, in press). Focusing on relational challenges is especially important in high-need districts where there is a diverse population of students since teachers' responsiveness substantially impacts students from non-dominant communities (Bang & Medin, 2010; Kang, in press; Nasir & Hand, 2006).

Contribution to the Interests of NARST Members

This study's overarching purpose is to help science teachers be more aware of their teaching moves and be more strategic while planning their FA. Since the FA enactment model was designed in collaboration with teachers, our findings are more accessible to teachers. Our results also enable a discussion about what it means to be more effective and how different teachers can change within time and experience and use a wider variety of tools that they think will best serve their purposes and allow more OTL for diverse students.

Acknowledgments

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