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From the teacher's eyes: facilitating teachers noticings on informal formative assessments (IFAs) and exploring the challenges to effective implementation

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ABSTRACT
This study focuses on teachers' use of informal formative assessments (IFAs) aimed at improving students' learning and teachers' recognition of students' learning processes. The study was designed as an explorative case study of four middle school teachers and their students at a charter school in the northeastern U.S.A. The data collected for the study included a history of teaching questionnaire, video records of the teachers' IFA practices, ethnographic interviews with teachers, and field notes from classroom observations. These data were analysed from a sociolinguistic perspective focusing on the ways that classroom discourse and reflective interview conversations constructed ways of viewing assessment. The findings from the analysis of the classroom discourse showed that teachers use three different types of IFA cycles, labelled as connected, non-connected, and repeating. Teachers' reflections on video cases show that teachers can learn to view in-the-moment interactions in new ways that can guide IFAs. We concluded that teachers' perspectives on the effectiveness of IFAs are an important, but often neglected, part of building a robust, interactive classroom assessment portfolio.

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Formative assessments; teachers' noticing; video reflection; discourse analysis

Introduction

Formative assessments are instructional tools used to inform instruction and scaffold student learning (Keeley, 2008). The use of formative assessments helps teachers guide their instruction and provide students with more frequent feedback on their progress (Bell & Cowie, 2001; Black & Wiliam, 1998). Formative assessments are an important component for innovating classroom environments that support teaching and learning. The seminal report by the National Research Council in the U.S.A., *How People Learn: Brain, Mind Experience and School,* examines such environments in four categories as learner-, knowledge-, assessment-, and community-centred (Bransford, Brown, & Cocking, 1999). In a learner-centred environment, the teacher values the ideas, experiences, and beliefs students bring into the classroom. Formative assessments can be used to elicit students' preexisting ideas. A knowledge-centred environment is one in which teachers determine educational goals, reshape these goals based on students' prior knowledge,

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and make the goals explicit to students. Formative assessments are beneficial in monitoring students' progress towards these goals and ascertaining that students learn key concepts along the way. Assessment-centred environments give students opportunities to evaluate their own ideas, and thinking and formative assessments can facilitate 'making thinking visible' to students. Community-centred environments are realised when students share their ideas and learn from each other. Effective formative assessment activities aim to encourage students to express their ideas publicly, argue against other claims, and reflect on these ideas to form a clarified scientific explanation (Bransford et al., 1999; Keeley, 2008).

Formative assessments can be used in different ways. They can be formal (i.e. pre-planned, scored, and recorded) versus informal (i.e. spontaneous, quick, not scored, and unrecorded). Many times the evidence of student learning collected through formal formative assessments (e.g. quizzes, homework, and projects) can be too late to 'de-programme' the instruction and make changes that will impact students' learning (Angelo & Cross, 1993). While formal formative assessments are helpful to understand teacher and student progress (Bell & Cowie, 2001; Black & Wiliam, 1998), they may not be enough for a comprehensive assessment of the dynamic social construction of scientific knowledge and students' skills to reason, argue, and evaluate scientific ideas. Informal formative assessments (IFAs) that are blended in everyday instructional activities can be used to collect evidence of learning each time students are participating in classroom discourse. IFA practices can be observed in a variety of forms such as orally in students' questions and responses, written in science notebooks, inscriptional in drawing, practical during an investigation, or non-verbal in body language (Ruiz-Primo, 2011).

Recently, science education researchers started to study IFA activities that are constructed through teacher–student interaction. They focused on the impacts of these assessments on students' learning of science, as well as some general challenges that teachers may have during implementation (e.g. Duschl, 2003; Duschl & Gitomer, 1997; Ruiz-Primo & Furtak, 2007). To date, few studies have examined how teachers learn effective implementation of IFAs considering the practical dimensions of classroom implementation. Indeed, the Committee on Developing Assessments of Science Proficiency in K12 in the U.S.A. (NRC, 2014) advocated for the importance of these assessments to 'elicit students' thinking about disciplinary core ideas and cross-cutting concepts by engaging them in scientific practices' (p. 5). This committee also asserted the challenge to examine the nature of design, implementation, and interpretation of these assessments by teachers. Teachers need support in understanding how to make such assessments effective. Teachers' perspectives of effectiveness are an important but often neglected part of building a robust, interactive classroom assessment portfolio.

In response to the above call, in this study, we developed a video-based professional development (PD) where teachers reflect on video cases for the effectiveness and practicality of IFA cycles. Through these video-case reflections, we explored the use of a type of IFA that is constructed during instructional dialogues between teachers and students. The purposes of these IFAs include improving students' learning and teachers' frequent recognition of student understanding. Through observations in middle school science classrooms and teachers' guided reflections on their practice, the study aimed to examine the influence of such reflections on evolving teaching conceptions of effective

IFA practices within the realities of science classrooms. To achieve this aim, the following questions were addressed:

(1) In what ways do middle school science teachers use IFAs prior to having opportunities to engage in video-case reflections regarding their assessment practices?
(2) In what ways do video-case reflections on assessment activities support middle school science teachers' conceptualisation of effective IFAs?
(3) What are the challenges that practicing teachers face during effective implementations of IFAs?

Theoretical and conceptual background

Reshaping assessment under the influence of sociocultural views

Recent research in science education and policy documents state that students should not only learn known theories in science, but also understand the journey scientists take to develop and strengthen these theories through scientific practices such as argumentation and data modelling. In such a journey, students should also attain the skills necessary to criticise, compare, and contrast the theories, and build knowledge and affiliations to eventually contribute back to the field (College Board, 2009; Gitomer & Duschl, 2007; NGSS Lead States, 2013; NRC, 1999, 2012). These are the skills that cannot be learned by only memorising conventional scientific facts and theories. Rather, students need to experience the construction of knowledge through active participation in classroom discourses that have been influenced by the cultural and historical backgrounds of students and teachers (Driver, Asoko, Leach, Mortimer, & Scott, 1994). For this reason, a detailed analysis of the classroom discourse has become the main focus of many science education studies during the last 20 years to understand the nature of student learning (Kelly, 2007).

Discourse in science classrooms has also been studied as a way for teachers' assessments of student improvement through different strategies including questioning and feedback. These informal and more frequent assessments involved in the classroom conversations are necessary to establish a basis of an assessment system (Ruiz-Primo, 2011). This assessment system is 'externally coherent'; that is, assessment systems should be consistent with 'accepted theories of learning and valued learning outcomes' (Gitomer & Duschl, 2007, p. 289). Therefore, the sociocultural theories and learning outcomes outlined in the new standards in the U.S.A. call for classroom-based assessment practices that are constructed through classroom discourse (NRC, 2014).

Models of assessments constructed through classroom discourse

Science education researchers developed descriptive models of how assessments were constructed through conversations among teachers and students by considering the common discursive turns of the classroom. Earlier research on these models were the description of commonly observed moves of classroom discourse structure as three-step Initiation–Response–Feedback/Evaluate (IRF/E) (Christie, 2002; Mehan, 1979; Sinclair & Coulthard, 1975; Wells, 1993).

Later, in an effort to support teachers' understanding of inquiry-based conversations, Duschl and Gitomer (1997) and Duschl (2003) introduced teachers to a model of *assessment conversations*. These assessment conversations have three parts: The teacher *(1) receives, (2) recognises,* and *(3) uses* information provided by the students. To receive information, the teacher arranges small group activities and tasks during which students can display their understanding. The recognition of student response involves the teacher's careful analysis of student understandings by considering the conceptual goals of lessons and also synthesising students' ideas. Finally, the teacher uses what students have learned in order 'to evaluate previous efforts, meanings, and understandings, and performances' and to improve students' understanding, meaning making, and performances. Although these assessment conversations are fostered by an inquiry environment, teachers mentioned implementation challenges such as the nature of science content. These teachers also expressed that they need to spend more time in preparing students for the multiple choice tests required by their states, and as a result, they had less time for using assessment conversations.

In 2005, Scott and Mortimer's work on communicative approach described four different types of talk in science classrooms: non-interactive/authoritative, non-interactive/dialogic, interactive/authoritative, and interactive/dialogic. IRF sequences were observed in interactive discourses, mostly in the interactive/authoritative type. In the interactive/dialogic classroom type, Scott and Mortimer (2005) also found another pattern of discourse, I-R-F-R-F- … , 'where the elaborative feedback (F) is followed by a further response from the student (R), and so on' (p. 401). The I-R-F-R-F- … pattern was mostly observed in interactive/dialogic type of classroom talk and suggested as a discursive pattern for science classrooms aiming for student-driven inquiry environments (Chin & Osborne, 2008; Scott & Mortimer, 2005).

More recently, Ruiz-Primo and Furtak (2007) introduced the ESRU (Teacher Elicits - Student Responds - Teacher Recognizes - Teacher Uses Students' Respond) cycle to three middle school science teachers at the beginning of the study. They claimed these ESRU cycles are different from the traditionally observed IRF/E cycles, in that the ESRU cycles give importance to the way that teachers not only recognise and but also use student responses to construct scientific explanations. During this cycle, the teacher *elicits,* the student *responds,* and then the teacher *recognises* and *uses* the information related to scientific content. According to the results of their study, IFAs can provide more frequent feedback to the teacher to monitor the classroom activities, and the effective use of these cycles (more complete cycles) results in better scores in formal written assessments.

In this study, we use a synthesis of these models (Figure 1) to describe a learning environment for middle school teachers. According to this model, the teacher initiates the IFA cycle and one or more students provide responses. The teacher evaluates these responses as relevant, partially relevant, or irrelevant to the current topic. At this point, the teacher makes a decision to ignore or recognise students' responses by paraphrasing, taking votes, and so forth. After recognising, the teacher either leaves the cycle or uses students' responses to help the class progress towards a more sophisticated scientific explanation. This model was used as a draft to guide the observations of classroom interaction. The model also set a criterion of selecting a variety of illustrative video cases. Informed by

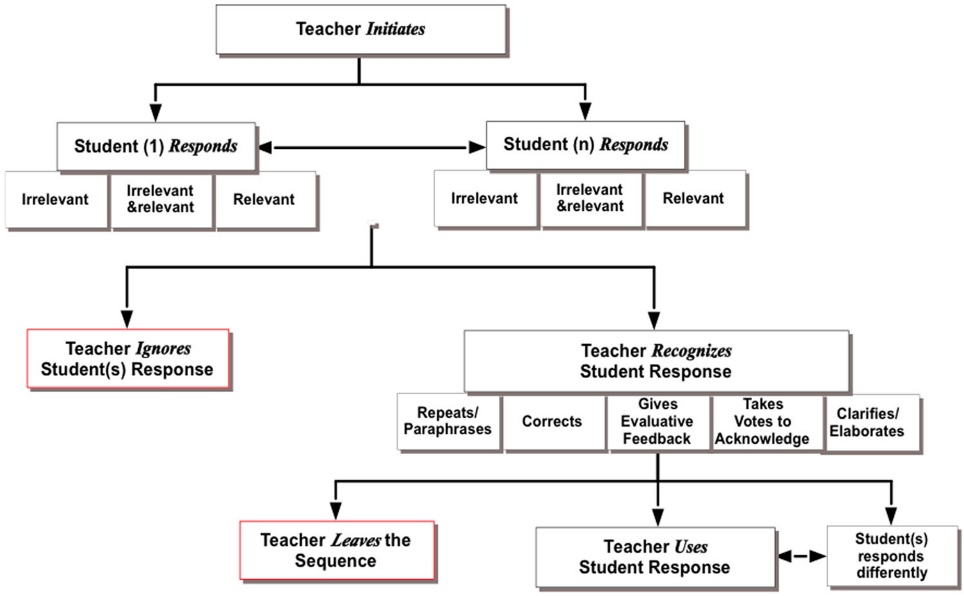

Figure 1. Guiding model for informal formative assessment cycle.

the previous studies (Duschl & Gitomer, 1997; Ruiz-Primo & Furtak, 2007; Scott & Mortimer, 2005), this criterion was the completeness of the model.

Teachers' professional noticing of effectiveness of IFA

Although the benefits of formative assessments have been widely accepted, studies have shown that such assessments are difficult for teachers to implement (Furtak, 2012). In a recent study, Shavelson et al. (2008) found that the gap between effective formative assessment envisioned by researchers and what is implemented in classrooms is significant. Teachers need extensive support to integrate these assessments into their classroom practice (Atkin, Coffey, Moorthy, Sato, & Thibeault, 2005). To provide such support, we first need to understand what an effective IFA cycle looks like and consider the dimensions of practicality in classrooms.

The effectiveness of IFAs. In this study, we choose to define the effectiveness of IFAs by using the conceptual framework from Thompson and colleagues' study on *rigour* and *responsiveness*. Their study showed evidence that rigour and responsiveness can support students' progression towards more sophisticated understanding of scientific ideas and create equity in science classrooms. Adapting from Thompson et al. (2016) to the case of an IFA, rigour is achieved when students are exposed to accepted scientific concepts and practices to make progress in their ideas. On the other hand, IFAs can be low in rigour if teachers and students give short responses that are either off task, superficial, or heavily dependent on memorisation of facts. IFAs can be responsive if the dialogue includes the following dimensions: '(1) building on students' scientific ideas; (2) encouraging participation and building classroom community; [and] (3) leveraging students' lived experiences and building scientific stories' (Thompson et al., 2016, p. 7). Through video-based PD, we support the conceptualisation of rigour and responsiveness in their IFA cases, their decision-making process, and the ways to improve the IFA cases.

Considering dimensions of practicality. Although studies justify the importance of creating rigour and responsiveness in science classrooms, we need to consider *dimensions of practicality* while suggesting an implementation of any reformist idea (Janssen, Westbroek, Doyle, & Van Driel, 2013). Teachers might improve on the use of effective IFAs that are rigorous and responsive interactions if they see such interactions are practical. Studies identified three dimensions of practicality that determine teachers' decision-making process during teaching. The first dimension is instrumentality, which refers to specified procedures that are valid for the classroom such as a local curriculum or a set of strategies on how to implement a novel idea. The second dimension is congruency, which is how well the suggested novel idea fits into the context of the teaching environment. The third dimension is the cost; the effort and resources needed to deploy the idea such as time and knowledge (Doyle & Ponder, 1977; Janssen, Westbroek, & Doyle, 2014). The need for practicality makes in-the-moment interactions complex as teachers have to think about multiple goals at the same time and make a quick decision. In the case of IFA, teachers need an enormous amount of support not only to conceptualise an effective IFA cycle and the role of these effective cycles in learning and assessment, but also for their decision-making on their practices (Janssen et al., 2013).

*Teachers' noticing of features of effective IFA practices within the dimensions of practicality***.** Teacher education researchers utilised the concept of professional vision from anthropology (being able to highlight and code the important segments during teaching activity) to understand how teachers select and attend to classroom practices and student ideas in the classroom (McDonald & Kelly, 2007). One main aspect of professional vision is to be able to notice essential features of an activity, tool, or data by gaining expertise in your field (Goodwin, 1994). Since our aim is to support teachers to evolve in their conceptualisations of effective IFA practices, teachers' noticing of elements of IFA practices is crucial for this study. Research on teacher noticing commonly show that what the teachers see determines the nature of the in-the-moment discourse (Jacobs, Lamb, Philipp, & Schappelle, 2011; Schoenfeld, 2011). For example, Jacobs, Lamb, and Philipp (2010) developed a PD activity to support teachers' noticing of children's mathematical thinking while solving math problems. As a result of the PD, they saw evidence of a shift towards greater utilisation of children's thinking and making links to effective teaching practices such as using students' previous knowledge. The important steps in noticing are:

> (a) identifying what is important or noteworthy about a classroom situation; (b) making connections between the specifics of classroom interactions and the broader principles of teaching and learning they represent; and (c) using what one knows about the context to reason about classroom interactions. (Van Es & Sherin, 2002, p. 573)

One way for teachers to experience these steps and thus be prepared to reason about their in-the-moment decisions is through video-case reflections (Sherin, 2004). Video cases can also help teachers 'develop sensitivities' for disciplined noticing, which is improved by gaining professions in their disciplines (Mason, 2002). In our study, to support teachers' improvement of professional noticing on their decision-making processes, that is, to improve their sensitivity on the effective use of IFA within the dimensions of practicality, we designed a collaborative reflection environment on video cases of IFA practices. The video cases were chosen from participant teachers' own classrooms due to prior research findings that teachers could see richer, more contextualised information while watching their own videos (Zhang, Lundeberg, Koehler, & Eberhardt, 2011).

Although there are a number of recent studies using video-case reflections to support teachers' noticing and another body of research on effective classroom interaction (e.g. IFAs), this study is different in the way that *it includes (1) teachers' decision-making processes on the effective implementation of IFA practices within the realities of classroom and (2) perspectives on what makes a momentary IFA cycle effective within the dimensions of practicality*.

Methods

This is an exploratory, qualitative case study that focuses on the IFA practices of four local middle school teachers teaching science (Yin, 2003). This study uses ethnographic data collection and analyses methods, that is, passive and active participant observations of middle school science classrooms, ethnographic interviews with teachers during their video-case reflections (Spradley, 1979), field notes taken by the researcher (first author of the study), and discourse analysis with an ethnographic perspective (Green & Wallat, 1981).

Study setting and the participants

The data of this study were collected at a local charter school, a free-tuition public school serving grades five to eight located in the northeastern U.S.A. The school has only four classrooms, two of which are a mix of the fifth and sixth grades and the other two are a mix of the seventh and eighth grades. Each classroom has two teachers: one lead teacher and one assistant teacher. One characteristic of the school is that it has a project-based curriculum. The curriculum is divided into authentic projects, for example, the Civil War, Medical School, the Institute of Neurology, and Finance. This study was carried out in two classrooms of this local charter school that were conveniently selected due to their willingness to improve instruction through research. We selected four projects (two from each classroom) to videotape based on the respective relevance to science content (Table 1).

A history of teaching questionnaire helped us identify teachers' classroom experience and background in science. Pseudonyms replaced the real names in this questionnaire. One was a fifth/sixth-grade lead teacher, *Charlotte* (18 years of teaching experience), and assistant teacher *Daniel* (eight years of teaching experience). Charlotte has a B.A. degree in psychology and a dual M.Ed. degree in elementary education and special

Table 1. The design of the research.

		Science teachers	
		Charlotte and Daniel	Sawyer and Kate
Scientific Projects	Scientific Project #1	Medical School	Institute of Neuroscience/Designing Scientific Research
	Scientific Project #2	Oceanography	Construction and Physics Laws

education. Charlotte took a few courses in biology, earth science, and chemistry while working on her bachelor's degree. Daniel has a B.S. in meteorology with an emphasis in Earth systems. He then was certified as a middle school mathematics teacher. The other classroom was a seventh/eighth-grade class with a lead teacher *Sawyer* (20 years of teaching experience) and assistant teacher *Kate* (six years of teaching experience). Sawyer holds bachelor's degrees in English and adolescent psychology, a master's degree in curriculum and instruction, and a Ph.D. in instructional systems. Sawyer took a few applied science courses while working on his bachelor's degree. Kate has a B.S. in environmental interpretation and outdoor recreation education with a minor in English. She also has an M.Ed. and her teaching certification in English. As required by her B.S. degree, she took applied science courses.

Data collection procedures

Data were collected in five sequential phases (Table 2) under two main categories: classroom observations and researcher–teacher meetings (RTMs).

Classroom observations. The data set for this study comes from 50 hours of classroom observations which are videotaped. There were two sets of classroom observations during which the researcher set up two cameras in each classroom for recording and took field notes. During the first set of observations (33- and 50-minute-long science classes), the researcher took an *etic* perspective and did not talk about the specific aims of the study with the teachers. The data from this set of observations came from the videotapes and field notes of everyday interactions during two authentic projects: the Medical School project (12/02/09–03/05/10) and the Institute of Neuroscience/Designing Scientific Research project (12/02/09–04/16/10). During the second set of observations (27- and 50-minute-long science classes), the researcher took an *emic* perspective where she was interacting with the teachers and students, having informal meetings with the teachers about their assessment activities during the breaks and occasionally guiding the teachers during their practice. The data from this set of observations came from the videotapes of

Table 2. The sequential phases of the study.

Phase 1	Observation 1 on Scientific Project 1 Teachers' own way of using informal formative assessments (IFA)	Research Question# 1 In what ways do middle school science teachers use IFA prior to having opportunities to engage in video-case reflections regarding their assessment practices?
Phase 2	RTM #1 after Scientific Project 1 Teacher reflections on IFA in general Watching video cases Teachers' reflection on their own video cases selected by the researcher on their use of IFA	
Phase 3	RTM #2 Teachers' reflections on IFA literature (Ruiz-Primo paper and summary)	Research Question# 2 What are the components of an effective intervention to foster teachers' reflection on IFA?
Phase 4	Observation 2 on Scientific Project 2 Teachers' way of using IFA after meeting with the researcher	Research Question# 3 In what ways do video-case reflections on assessment activities change middle school science teachers' IFA perspectives and practices as stated by teachers?
Phase 5	RTM #3 after Scientific Project 2 Teachers' reflection on their video about the way that they are using IFA after meeting with the researcher	Research Question# 4 What are the challenges middle school science teachers faced during the implementation of IFA?

classroom activities and field notes of everyday interaction with the teachers during two additional authentic projects: the Oceanography project (03/15/10 and 05/28/10) and the Physics Laws in Action project (04/16/10–05/28/10). For both sets of observations, field notes were recorded to keep records of how teachers interpreted the change in their assessment practices.

*Video-based PD***.** The video-based PD was carried out as RTMs and recorded by researchers. These meetings were designed so that the teachers could have a closer look into their practice through selected video cases, reflect on their practice under the researcher's guiding questions, and express their challenges or problems for using an effective IFA cycle. The first author held three meetings with teachers, each about one hour long. The first meeting was designed after the observations of the Medical School and Institute of Neuroscience/Designing Scientific Research projects, the second meeting was held to discuss the academic literature regarding formative assessment with teachers, and the third meeting was arranged right after the observations of the second projects, Oceanography and Physics Law in Action. The researcher met with the fifth- and sixth-grade teachers (Charlotte and Daniel) and seventh- and eighth-grade teachers (Sawyer and Kate) separately due to the different timelines and subject matter in their science projects. The interview questions started with broad questions on reasons for using IFAs, teacher's noticings, challenges, and changes in practice. Teachers' responses to these questions were further elaborated with sub-questions.

In preparation for these meetings, teachers' knowledge-based reasoning was supported by a reading package on IFA models. After an initial meeting with the first author, the teachers were given a paper that summarises the theoretical IFA models prepared by the researcher and an article by Furtak and Ruiz-Primo (2005) in *Science Scope*, a teacher practitioner journal for middle school science teachers. These materials were used for the discussion during the second RTM. The researcher facilitated the reflections of two co-teachers through semi-structured interview questions. Both the reading package and the researcher's semi-structured questions guided the teachers to make connections on broader principles of effective IFA and use this knowledge to interpret their decision-making and future actions.

Selection of IFA cases. Researcher's field notes during the six months of observing the two classrooms helped to ascertain how the teachers arranged science learning in their classroom cultures and how different kinds of assessments were embedded in students' learning processes. We used 'mapping' (Powell, 2010) – a qualitative method to summarise the one-year overall ethnography of the two classrooms videotaped during the 2009/2010 academic year (Tables 3 and 4). Mapping helped to analyse the conceptual sequence of scientific units and designed classroom events (activities) for the attainment of the learning goals of the scientific units. We call these 'timelines' in the current study.

The timelines (Tables 3 and 4) show how the content was sequenced in terms of projects and then divided into smaller instructional units, by focusing on how the participants structure their time and activity. The timelines were used to document the classroom practices and provide a basis for theoretical sampling. The selection of the projects to videotape was based on the respective relevance to science content relative to the researcher's background in science. All units within the selected projects were recorded; however, the units and daily activities involving teacher–student interactions were chosen for analysis. Tables 3 and 4 give information about the description of every unit recorded and daily activities

Table 3. Timeline of the overall ethnography for Charlotte and Daniel's classroom (2009/2010).

Project title	Date	Units	Unit title	Dates	Content of the unit	Description of the daily event from which IFA cases were selected
Civil War	09/08/09–11/25/09	No videotaping – No science content				
Medical School	12/02/09–03/05/10	1	3-D Cell City	12/02/09 – 12/15/09	Cell structures and organelles	Microscope Laboratory: How to use a compound microscope?
		2	It is all in the Genes	01/04/10 – 01/08/10	DNA and Mendelian Genetics	Role play on how traits pass through generations Whole-class circle discussion on recessive and dominant genes
		3	Gross Anatomy	01/11/10 – 01/15/10	Known body parts – common conditions and diseases	No IFA case selection
		4	Human Body Systems	01/18/10 – 02/12/10	All body systems in detail (circulatory, respiratory, etc.)	Whole-class circle discussion on how heart-blood, oxygen is related Whole-class circle discussion on the circulatory system Online activity on reviewing glands in the human body Review of what has been learned about skin
Oceanography	03/15/10–05/28/10	5	Diseases and Conditions	03/15/10 – 03/05/10	Diseases in the Human Systems – symptoms, diagnosis, and treatments	No IFA case selection
		1	What in the World?	03/15/10-04/09/10	Oceans on the World	Presentations on different oceans of the world
		2	What puts the Ocean in Motion?	03/15/10-04/09/10	Waves, tides, currents	Experiment on Water waves High vs. Low Tides Lab activity
		3	Ocean Exploration	04/12/10-05/03/10	Previous and current scientists' research on Oceans	No IFA case selection
		4	Ocean Ecosystems	05/03/10-05/28/10	Coral Reefs, Ocean Food Chains	A video on the Great Barrier Reef and students reflect on the video. Explanation of Kelp Forests Whole-class circle discussion Kelp Forest

selected for data analysis. The units involving activities based on independent work of the students were not analysed, and in the timelines they were labelled as 'No IFA case selection'.

These timelines were used to narrow down the sections for analysis (e.g. where more dialogic interaction was possible) as well as to eliminate the 'No IFA' sections. In the two classrooms used for this study, the scientific content was arranged as projects that were connected to the real-life practices. As shown in Table 3, Charlotte and Daniel's

Table 4. Timeline of the overall ethnography for Sawyer and Kate's classroom (2009/2010).

Project title	Date	Units	Unit title	Dates	Content of the unit	Description of the daily event from which IFA cases were selected
Finance	09/08/09–11/25/09	No videotaping – No science content				
Institute of Neuroscience	12/02/09–02/01/10	1	Introduction to the nervous system	12/02/09 – 12/15/09	The need for nervous system and the basic parts of the nervous system	Whole-class discussion and brainstorming on the need for nervous system and parts puzzle
		2	Functions of the nervous system	01/04/10–01/08/10	How the nervous system helps the functioning of other human body systems	Whole-class discussion and independent research
		3	Brain	01/11/10–02/01/10	Parts of the brain and how brain works	Brain modelling and one-to-one brain talks
Designing Scientific Research	02/02/10-–04/16/10	1	The Concept of Variables	02/02/10–02/12/10	Defining & exemplifying independent & dependent variables	No IFA case selection
		2	Research Questions and Hypotheses	02/16/10–02/26/10	Writing research questions and hypothesis	Falling object experience and whole- class discussion on formulating questions Whole-class questioning on writing hypothesis and independent research One-to-one questioning on writing hypothesis and independent research
		3	Scientific Method	03/15/10–04/09/10	Making decisions on the methods used in scientific research	No IFA case selection
		4	Reporting Results from Scientific Research	03/03/10–04/16/10	Conducting the designed experiments and reporting the findings	No IFA case selection
Physics Laws in Action	04/16/10–05/28/10	1	Gears, Gearing, and More Test	04/17/10–05/05/10	Constructing cars and testing gears to physical processes	No IFA case selection
		2	Trebuchets	05/05/10–05/28/10	Understanding how trebuchet works and	Teacher's modelling of trebuchet and discussion on physical laws to show how it works Students' construction of trebuchets in small groups

fifth- and sixth-grade classroom completed three main projects during 2009/2010 academic year: Civil War, Medical School, and Oceanography. The researcher recorded the Medical School project for understanding the authentic assessment practices of teachers, and after the first RTM, the Oceanography project was recorded to collect evidence on the teachers' reflections of the changes they experience in their IFA practices after the meetings. Table 4 shows the four main projects in the seventh- and eighth-grade classrooms completed during 2009/2010: Finance, Institution of Neuroscience, Designing Scientific Research, and Physics Laws in Action. The Institution of Neuroscience and Designing Scientific Research projects were recorded to collect evidence of assessment prior to video-case reflections and Physics Laws in Action was recorded after the RTMs. The assessment artefacts collected from these two classrooms showed that the teachers used spoken and written discourse to evaluate the progress during each project.

The video cases were selected before the first meeting by the researcher. To select these video cases, the researcher determined the IFA sequences among all video records of everyday classroom activity during the three-month-long science project. The initial guiding model of IFA helped in this selection. Three other criteria to balance the range of IFA sequences were selected: reaching the intended educational aim of the cycle, different phases of the projects (e.g. engage, elaborate, and sum-up), and approved participants in the Institutional Review Board process. For the set of data from these lessons, Studiocode (a software to analyse video) was used to identify IFA cases for each lesson. We listened to each lesson and assigned a colour to a different type of interaction (e.g. one-on-one and whole-class discussion). Each IFA case during a whole-class discussion was numbered. We then relistened to the numbered IFA cases to determine the most typical IFA cases where similar interaction flows will be seen many times. After coding the IFA cases by using Studiocode, illustrative IFA cases were selected for RTMs and detailed analysis.

Analysis

Teachers' use of IFAs in science classrooms. At the beginning of this study, we identified the ways IFA was used by the four practicing teachers within real-life project-based learning environments. In creating these environments, the teachers aimed to relate students' daily life events to scientific concepts and to help students use scientific practices to create solutions to real-life problems. The examples in this section have this overarching goal.

Table 5. IFA cases for the RTMs (Charlotte and Daniel).

Case label	Type of IFA	Description of the daily activity	Phase in the project	Total # of IFA per activity
A	Connected	Microscope Laboratory: How to use a compound microscope?	Engage/guided practice	27
B	Connected	Whole-class circle discussion on recessive and dominant genes	Explain in large group discussion	9
C	Connected	Whole-class circle discussion on how heart-blood and oxygen is related.	Elaborate in large group discussion	12
D	Non-connected	Whole-class circle discussion on the circulatory system	Explain in large group discussion	17
E	Non-connected	Online activity on reviewing glands in the human body	Review	8
F	Repeating	Review of what has been learned about skin	Review	19

Table 5 shows the selected IFA cases (totalling 191) for the RTM with Charlotte and Daniel (fifth and sixth grades). As shown in Table 3, six cases were selected from Charlotte and Daniel's classroom (A–F). The type of the cycle was identified as 'connected' if the teachers used student responses to continue the following cycle or activity (i.e. to make immediate instructional changes). The cycles identified as 'non-connected' were those when the teachers did not use students' responses during their subsequent step (i.e. did not continue with the thread of students' idea). Another type of cycle was identified as 'repeating cycles' where the teachers used a set of similar questions to initiate consecutive cycles. Table 5 also shows the description and the phases of daily activities from the cases selected as well as the total number of IFA cases per activity. In a similar way, Table 6 shows the IFA cases (A–F) selected for RTMs with Kate and Sawyer (seventh/eighth grades) together with the types of these cases, description and phase of the activity, and the number of IFA cases per activity.

Identifying the ways of using IFAs: Coding the transcripts of IFA practice. After the selection, the cases were transcribed to analyse the discourse of the interactions during IFAs. By using the guiding model of IFA (Figure 1), the first author identified different patterns on teachers' use of IFAs in their classrooms. The transcript below shows an example of the transcripts and the coding used to analyse the IFA practice. The transcript below is from the video record of the beginning of an introductory microscope laboratory lesson, a part of a 3D Cell City unit conducted right before students were beginning to learn about the basic structures (e.g. membrane and cell wall) and organelles (e.g. nucleus) of cells (see Table 3 for the timelines). Transcripts were constructed by the turn of the speaker and coded by using the steps in the guiding model (Figure 1) together with explanations of the reasons for the teachers' actions. As shown in lines 14–16, Daniel uses (summarises) student responses to explain the use of the microscope. When the teachers' goal for asking the question or the subject matter content changed, the cycles were separated. These cycles were labelled as a different cycle when the teachers initiated another cycle (see lines 17–18 when Daniel asked a

Table 6. IFA cases for the RTMs (Kate and Sawyer).

Case label	Type of IFA	Description of the daily activity	Phase in the lesson	Total no of IFA per activity
A	Connected	Whole-class discussion and brainstorming on the need for nervous system and parts puzzle	Engage/brainstorming of initial ideas	22
B	Connected	Whole-class discussion on the functions of the nervous system	Engage	32
C	Non-connected	Brain modelling and one-to-one brain talks	Guided Practice	7
D	Non-connected	Falling object experience and whole-class discussion on formulating questions	Guided Practice	16
E	Repeating	Whole-class questioning on formulating hypothesis and independent research	Review	14
F	Non-connected	One-to-one questioning on writing hypothesis and independent research	Guided practice	8

question to check a student's understanding) or started lecturing independently of the students' responses.

	Time	Speaker	Line #	Transcription	Code
IFA Cycle 1	00:33:81	Daniel	1 2 3 4 5 6	These are the microscopes (*Pointing to the microscopes on the table*). I wanna know what you know about microscopes, either what they're used for or if you know any parts on the microscope and the technical names of the parts, or how do you go about using the microscope? So, thank you for raising your hands. Rory?	Teacher initiates – asking questions – making preexisting experience/ ideas explicit
	00:53:81	Rory	7 8	Well, I know what it's used for. It's used for looking at stuff closer than what the eye can see by itself	Student responds – on task
	01:05:30	Daniel	9	Cool, yup	Teacher recognises – gives evaluative feedback
			10	Grace?	Teacher recognises – takes another student's response
	01:07:80	Grace	11 12 13	Um, like, if you wanna see cells or from very underneath and look at that and it's, like, really figures. You can actually see it	Student responds – on task
	01:12:70	Daniel	14 15 16	Oh, so a cell is an example of something that's really small that we wouldn't necessarily be able to see with our naked eye or just our eyes. Okay	Teacher uses student response to explain the use of a microscope
IFA Cycle 2	01:19:30		17 18	But a microscope might help us to see something like that, Grace?	Teacher initiates – checking student understanding
	01:18:26	Grace	19	Yeah	Student responds – on task
	01:32:80	Daniel	20	Cool!	Teacher gives feedback – evaluation

Identifying teachers' learning processes and challenges: Coding teacher interviews. The analyses of teacher reflections were done by using Gee's discourse analysis method of looking at the building tasks of language (2005). One building task of language that will be used in this study is 'connections'. According to Gee (2005), one way to look at the discourse within the interview data is to search for 'themes, motifs, or images that co-locate (correlate) with each other; that is, themes, images, or motifs that seem to "go together"' (p. 153). Such related themes connect diverse parts of the interview together and give it a certain overall coherence and 'texture' (p. 153). The texture of the interview data from the RTMs was first constructed through the guided interview questions. These questions formed the phases of three meetings arranged with the fifth/sixth-grade and seventh/eighth-grade teachers separately. Following the research method of Gee, we segmented the interview conversations into phases of activity. These 'phase units represent activities marking the ebb and flow of concerted and coordinated action among participants, and reflecting a common content focus of the group' (Kelly, 1999, p. 2). Thus, the phases of the meetings are constructed under a common action or content focus. The first meeting involved the phases of (Table 2):

(1) Researcher's introduction of the focus and the aim of the study;
(2) Teachers' reflections on IFA prior to watching video cases from their own practices with a focus on students' knowledge and learning processes;
(3) Teachers' watching of video cases;
(4) Teachers' reflections on IFA after watching video cases from their own practices;

(5) Researchers' introduction of the IFA literature to teachers and handing the files containing the paper, which is the summary of the literature and Furtak and Ruiz-Primo articles on IFA for middle school teachers and published in the journal *Science Scope*, as well as the empty sheets for the teachers to write and draw their ideas about their own IFA model; and
(6) Researchers' explaining and clarifying the aim of the study on model development and initial ideas from the teachers for their model.

The second meetings had the following phases:

(1) Teachers' reflections on a paper on the previously developed models of IFA prepared by the researcher and an article by Furtak and Ruiz-Primo (2005) in the journal *Science Scope*; and
(2) Teachers' comments and critiques on the guiding model of IFA (Figure 1).

The third meetings had the following phases:

(1) Teachers' reflections of IFA related to the changes in their perspectives and practice after completing another scientific project; and
(2) Teachers' reflections on IFA in terms of challenges due to internal (inside the classroom) factors, which are further analysed for this study, and external (outside the classroom) factors, which are outside the scope of this study.

The transcript below shows an example of how the data from RTMs were coded. These data were from the first RTM with Sawyer and Kate (seventh/eighth-grade classroom teachers). The first column shows the number of the phase and the second describes the phase (e.g. Phase #2 is during 'Teachers' reflections on IFA prior to watching video cases from their own practices with a focus on students' knowledge and learning processes'– see the list of the phases stated above). Within each phase, every turn (by speaker: Sawyer or Kate) was coded to look at the common themes within and across the phases of the meetings. The code contained a main category (e.g. 'The aim of IFA') and a sub-category (Understanding students' needs and interests).

Phase #	Phase description	Speaker	Talk	Code
2	Teachers' pre-reflections on IFA related to students and student learning	Sawyer	Um, it's through informal questioning or questioning, I think, you can hone in on student need. You can also, um, hone in on student interest where if you're talking about – today we're talking about biomes. If a student has a particular interest, you can begin to tailor a lesson, tailor a project, tailor a specific activity to the interest of that student and hopefully engage them more. There is much – much of what we do is working towards engaging the students, through the student, taking their interest.	The aim of IFA – Engaging students through - Understanding students' needs and interests - Tailoring a lesson, a project, a specific activity to the interest of the student

(*Continued*)

Continued.

Phase #	Phase description	Speaker	Talk	Code
		-	-	-
		-	-	-
3	Teachers' pre-reflections on IFA related to teachers and teacher learning	Sawyer	Yeah that's trying to tease out that they know a lot more and also put it in terms that they understand input and output. Um, and really help them to see, **begin** to see that there is a lot there but it's also a fairly simple thing going on at one level as an input and output [to the brain], but you know it takes a way to do it.	Justification of leaving IFA Cycle – When the aim is just starting the talk about scientific concepts
		-	-	-
		-	-	-
5	Teachers' reflections video cases	Kate	Right. It's something [that] comes up like the Brady thing. You know, Sawyer questioned [Brady's question on electrodes]. "What are you talking about? Tell us **more** about [what you understand from pickle things]. Oh, **okay**, are you talking about this? Oh, that's right. You know how the body works; you know we use – there is electricity and chemicals. You know that makes up the way our body functions and … yeah.	The aim of IFA – Understanding student reasoning of scientific concepts
		-	-	-
		-	-	-

Findings

Considering the illustrative cases of IFA selected from the data of the study, the use of IFAs varied among different teachers, classrooms, and phases of the lesson, yet they can be categorised under three types: connected, non-connected, and repeating cycles. We report the IFA types in our context for two reasons. First, we sought to better understand our context and elaborate on each type of IFA through teachers' reflection on their own videos. This way we can understand why and when teachers use each type and choose to make it an effective assessment prompt. Second, we have not seen many studies focused on the repeating cycles where teachers persist in asking and reframing questions to draw students into an instructional conversation.

Types of IFAs in classroom discourse

IFA cycle type# 1: Connected cycles. In this study, we use the word 'connect' based on the teachers' preference instead of 'use' as in other research on IFA (Ruiz-Primo & Furtak, 2007). The transcripts from the data of the two classrooms in the local middle school showed that teachers used connected IFA cycles. In these cycles, the teachers received responses from students and recognised the responses and, more importantly, the teachers included students' ideas in their own explanation. For example, the transcript below is from the lesson right after the students engaged in a role play about personal traits that we carry through our genes (see timeline for the daily activity 'Role-play on how traits pass through generations', on 01/04/10 in Table 3). In this role play, students were exploring their unique personal traits that could come from their families and distinguishing them from that of their friends in the classroom. In the following lesson, Charlotte (fifth/sixth-grade lead teacher) was elaborating on how traits pass through generations during a whole-class discussion. She had the aim to teach the concepts of ‘recessive’ and ‘dominant’ genes. In the IFA case below, without using the scientific terms, she initiated with a question (lines 1–4) to understand how the students were reasoning about the passing of traits from generation to generation. Upon getting an on-task response from Mike (lines 5–12), the teacher gave an evaluative feedback to encourage more students to share their ideas by saying ‘Whoa, Dr. Mendel is back. That’s cool!’ Right after the acknowledgement, the teacher did not close the cycle. Instead she attempted to integrate Walter’s explanation to her following question while she was asking for more ideas. Charlotte (lines 14–15) followed by saying ‘Did you understand what he was saying? What do you think?’ The cycle continued with an explanation from Jackson and then the teacher used the word ‘dominant’ to connect Jackson’s response to the follow-up question and asked if other students could relate their ideas to the scientific terminology. Stu (lines 30–34) gave an example for recessive genes, which shows an understanding of the concept. Then, the teacher used an eye colour example to go to the next sequence on how scientists can predict passing of traits based on dominant and recessive genes. Thus, this is a complete cycle that includes the teachers’ initiation, students’ responses (on task), and the teacher’s recognition and connection of the students’ responses to the next sequence.

Time	Speaker	Line #	Talk	Code
00:00:00	Charlotte (Teacher)	1 2 3 4	Your great-great-great-grandfather, great-great-great-great-grandmother, gets passed generation after generation after generation after generation. Which traits won’t get passed on? Great mysteries of life! What do you think, Mike?	Teacher initiates – asking questions – making preexisting experience/ideas explicit
00:23:81	Mike	5 6 7 8 9 10 11 12	I would think how a trait was stopped is, um, someone marries, someone else’s trait stops. Like, if I have some wife and then I have a kid and he marries someone else, his kid will not have the same traits as me, because his, um, wife’s traits will have some of his traits and his traits will go. So, they’ll go into the kids. So, it’ll be different or it could – he could have a dominant gene or she can have a dominant gene so it’s just two dominant genes.	Student responds – on task
00:54:31	Charlotte (Teacher)	13	Whoa, Dr. Mendel is back. That’s cool!	Teacher recognises – gives evaluative feedback
		14 15 16	What do you guys think? Did you understand what he was saying? What do you think? What? I’m open to all hypothesis or hypotheses. Tell me, what do you think?	Teacher recognises – takes votes to acknowledge
01:07:81		17	One second pause	
01:08:81	Walter	18 19 20	Well, like, if Ryan (*pointing to his friend*), like, marries some girl with blue eyes and he has brown eyes, and then they have a kid, their kid [will] probably have brown eyes.	Student 2 responds – on task
01:17:81	Charlotte (Teacher)	21 22	So, and is it just, like, I’m just guessing 50–50? How do you know?	Teacher recognises – elaborates on student response

(*Continued*)

Continued.

Time	Speaker	Line #	Talk	Code
01:22:81	Jackson	23	Brown eyes are usually [the] dominant gene.	Student responds – on task
01:24:81	Charlotte (Teacher)	24 25 26 27 28 29	What? Whoa, okay. 'I'm hearing, like, you guys are, like, on the same sort of level of thinking about genes and passing on and passing on and you have this idea of dominance and stuff. Talk to me Stu, what are you thinking? (*Stu is raising his hand*)	Teacher recognises – gives evaluative feedback Teacher connects – uses the term dominant from student 2's response Teacher recognises – takes votes to acknowledge
01:34:81	Stu	30 31 32 33	Well, I, I was kinda with that but – um, with the brown being the dominant genes – but since green is really unlikely, they don't ever know if it's gonna be dominant or recessive. So, I have – no, you really – no green eyes.	Student 3 responds – somewhat on task
01:54:81	Charlotte (Teacher)	34 35 36 37 38 39 40 41 42 43 44	So, maybe some of the traits that we can use to differentiate individuals. For example, eye colour, maybe 'you're saying that some of them we can predict somehow and maybe some of them are just totally random. You can't tell. So maybe that's true, and if that's true, you think maybe, um, scientists are working on trying to figure out how something could be figured out. Thinking on this kind of bothers us, doesn't it? We cannot figure things out. Sort of the way we're wired, we're inquisitive, inquisitive that way. And as we invent technology, we're using it to uncover the mysteries of life.	Teacher connects – teacher includes student examples to her statement that will open up the next sequence

While connecting students' example on eye colour, the teacher mentions that sometimes we can use our eye colour to 'predict' the trait for the next generation. However, she does not explain how this prediction can occur (lines 34–44).

Although this was an example of a connected cycle, at the RTM, Charlotte noticed that she was 'not responsive' to students' explanations on how exactly the eye colour is inherited from ancestors. For her, explaining the inheritance of eye colour depended on 'more than two genes' and it was 'very complex'. She then continued:

> You've (*looking at Daniel*) taught me that when I simplify things I need to be really careful. Because it's easy to simplify things to an incorrect level. I don't have time to learn and teach those details. (Charlotte, RTM#3, 14 May 2010)

Daniel added:

> Yeah, yeah. And I had a professor – that same thing, that was one of his things, was bad science. And I remember he had a 'bad science' website where it was all about all these concepts that are taught in elementary schools that are incorrect. (Daniel, RTM#3, 14 May 2010)

In this case, we can infer that Charlotte was making a decision between cost (limitations of her background knowledge) and responsiveness (to students' ideas). Despite students' efforts in trying to explain how eye colour is inherited from parents, the teacher wanted to be cautious in the limits of her knowledge to not provide the details. Therefore, Charlotte limited students' authority in changing the direction of the dialogue.

Below is another connected cycle from Daniel's laboratory on how to use a compound microscope (see timeline for 12/08/09 in Table 3). The teacher connects Alex and Gareth's ideas to his explanation (lines 18 and 19).

Time	Speaker	Line #	Talk	Code
04:29:80	Daniel (Teacher)	1 2 3 4 5	Now, Jason was talking about going into a cell, or he was trying to kind of explain how it is that we're able to see things. Does anybody wanna elaborate on that? What is going on? What is the process, Alex? What does the microscope actually do for [you]?	Teacher recognises – asks for elaboration from the class
04:43:78	Alex	6	It zooms in	Student responds
04:44:78	Daniel (Teacher)	7 8	It zooms in? Okay. That's absolutely correct, but anybody know how? Gareth?	Teacher recognises – gives feedback and asks for elaboration
04:55:29	Gareth	9 10	Um, I do believe that there is, like, um, an ultraviolet break in it.	Student 2 responds
05:00:93	Jason	11	No not exactly, it can …	Student 3 responds
05:05:42	Daniel (Teacher)	12	Shush … let Gareth finish. Let Gareth finish	Teacher is managing the conversation
05:10:02	Gareth	13 14 15	It's, um, it's pretty much incoming light in – uh, like, cuts the cell – ah, we could be able to go down into it and see the nucleus and all that.	Student 4 responds
05:22:82	Daniel (Teacher)	16 17 18 19	Okay. So you're thinking that there is some sort of source of energy that is penetrating the cell? ------------------------------------- So, we need light to be able to zoom into a very, very tiny cell. We also need mirrors …	Teacher recognises – asks for clarification Teacher connects students' responses

In this case, the teacher had to stop one student from responding (line 12). Jason started evaluating Gareth's response (line 11) and prompted the teacher to tell Jason that it was still Gareth's turn. Based on researchers' field notes, Jason was called the 'science student' by the teachers and students in the class, as he was known to watch documentaries or TV programmes related to science, read science magazines, and go on science-related field trips (e.g. bird watching). The teachers expressed that they liked Jason's interest in science. However, the teachers mentioned the challenge when Jason dominated the conversations by not letting other students express their ideas completely. During an RTM, Daniel noticed that he did not want Jason to disturb Gareth who is a 'shy kid', and he also mentioned that he wanted to 'clarify' Gareth's idea (lines 13–15), but it was a challenge. Then, he stated:

> Um, so with that, I guess, clarifying, it depends on the student's answer and only – you know, in my mind, I was thinking I'm doing [a] call that you know – okay, now raise your – if you think, if you agree; raise your hand if you disagree. And I assume that's [going to] get everybody obviously – get everybody involved. But I was thinking [of the] other case where the student who, you know, maybe [is] put on the spot if his answer's way too confusing, nobody agrees with them – and depending on the type of student, it can be, like, you know, they're – kinda of a blow. Um, but then on the flipside, you can be really confident,

> like 'So, how many people think that's right? The majority will, like, you know, the majority of the class [will] agree with him; like, that's gotta feel good. Like, you know, so used in that context, you know, [it] would be definitely valuable both in, you know, keeping the discussion going, but also the, you know, you know, highlighting – [the] student maybe [will] feel good and, you know …
>
> At the same time, you know, [it] can be [a] challenge if not done with that thought or just that sensitivity. (Daniel, RTM#2, 4/8/2010)

In this case, we can infer that the teacher, Daniel, is trying to make a decision between congruency (congruent with social norms) and responsiveness (to include students' everyday experiences). He thinks that when he lets science students talk, he can take a vote and there will be students who will be agreeing with him. However, when he lets shy students tell their ideas, he finds it a challenge to ask for a vote. If no student agrees, that will not be sensitive to the student. Insensitivity to students is not congruent with the social norms of open participation and respect that the teacher is trying to establish in his classroom through posters and student writings.

*IFA cycle type# 2: Non-connected cycles***.** Another main type of cycle that appeared in the IFA examples was the non-connected cycle, where teachers initiated the cycle usually by asking a question, students responded, and then the teacher either showed the recognition of the response and started another cycle or continued with his or her own explanation related to the idea. Below is an example of a non-connected cycle where Daniel (fifth/sixth-grade assistant teacher) was explaining about how the immune system defends our body against harmful microorganisms. Daniel wanted to use antibiotics to familiarise the subject to the students. Before using the example, he wanted to see if students know what 'antibiotics' were. In this cycle, when students raised their hands (lines 4–5), Daniel recognised that the students were familiar with antibiotics. Then, instead of using a follow-up question to understand what the students knew about antibiotics and how antibiotics work, Daniel just used his own explanation and then left the cycle (lines 8–12).

Time	Speaker	Line #	Talk	Code
00:00:04	Daniel (Teacher)	1 2 3	… medical establishment we worry about because you have germs that when you have antibiotics … Raise your hand if you have taken antibiotics before.	Teacher initiates – asks a question – polling
00:08:48	Students	4 5	Um, well … (most of the students are raising their hands)	Students respond – on task
00:08:98	Daniel (Teacher)	6 7	Probably most of you probably have [had] it one time or another, and antibiotics are …	Teacher recognises student response – agrees with students
		8 9 10 11 12	It's some sort of, um, a chemical or, um, that helps your body destroy the particular germ. Penicillin is, was the first antibiotic and it was derived from – or, or done from, um, from the yeast – or mold, I'm sorry, from a mold and that's where they were, they …	Teacher explains what antibiotics are and leaves the cycle

In this IFA, the teacher only assesses if students ever used antibiotics and he does not use the opportunity to assess students' everyday experiences and to connect these experiences to his explanation.

> That's what I was gonna say too. There are serious time constraints. That's why I have to theorize what's going next. It's first – circulatory system is one of the first systems, so

> there is a little bit more time. There is always different organs working together in this system. So, then you want to rush. I wish I asked one or two students [to] explain what antibiotics are. I assumed they knew, I think. (Daniel, RTM#3, 14 May 2010)

To the teacher, this was a challenge between cost (time) and responsiveness (to students' everyday experiences). However, the teacher sees that the way to improve the case is by asking students what antibiotics are.

Below is a transcript from Sawyer's (seventh/eighth-grade teacher) class on the nervous system. Sawyer's class started the nervous system project by watching a movie about dysfunction of the brain and the nerves as a previous activity (see the timeline for the daily activities on 01/04/10 in Table 4). Right after, Sawyer asked his students to give him a 'basic, concise definition of the function of the nervous system'. At one point during the conversation, the students mentioned how neurons help us to feel through our senses. Following this idea, one student (Andrew) mentioned neurotransmitters (lines 1–2) and then explained the relationship between neurotransmitters and feeling pain in the body (lines 4–6):

Time	Speaker	Line #	Talk	Code
08:04:78	Andrew	1 2	Um, neurotransmitters like serotonin and dopamine, they, like, like, carry information.	Student responds – on task
08:10:77	Teacher (Sawyer)	3	Yup	Teacher recognises – agrees with student response
08:11:76	Andrew	4 5 6	And, um, the more of each, um, each, um, like, substance there is, like, the stronger the pain, like, stronger the signal, like, there is more, like, like, milder strong pain.	Student responds – on task
08:26:26	Teacher (Sawyer)	7	Uh-hum.	Teacher recognises – agrees with student response
08:26:76	Andrew	8 9	The more neurotransmitters there is, the stronger the sensations.	Student responds – on task
08:30:26	Teacher (Sawyer)	10	Good. Serotonin and dopamine.	Teacher recognises – gives an evaluative feedback

In this IFA, the teacher ignores Andrew's ideas on sensations. This was due to a decision between cost (time) and responsiveness (to students' ideas) as in the previous case:

> Time. Definitely time. But here I should have recognized Andrew's response on sensations and that would – yeah, that would help me to have a flow in the conversation. (Sawyer, RTM#2, 4/5/2010)

Another similarity between the two non-connected cycles is that teachers see the way for improvement, whereas in connected cycles they did not report how they could improve their IFA cases.

IFA cycle type# 3: Repeating cycles. Other cycles that appeared in our data were repeating cycles, which can be either connected or non-connected cycles. These cycles occur when the teacher repeats the same or similar question to collect students' responses.

For example, in one of her lessons on human body systems (daily activity on the timeline: 'Whole class circle – Review of what has been learned about skin'; 02/09/10 in Table 3), Charlotte (fifth/sixth-grade lead teacher) was reviewing the sensory system by using online readings and activities. Students were taking turns reading the story about the sensory system on the smart board. After they finished each paragraph, Charlotte asked a question to see if the students were learning any new or interesting information from the online reading. In the following conversation, Charlotte asked the question 'Raise your hand if you learned something new from that paragraph' (lines 1–2). Then Charlotte repeated the question by saying 'Something new?' (line 6) and 'What else?' (line 10). In this case, Charlotte aimed to encourage more students to attend and help the teacher to summarise all the ideas at the end of the lesson. Like Wendy and Betsy (lines 4 and 7), other students used their new knowledge about the sensory system as Charlotte kept asking, 'What is new? Something new? Anything else? What else?' At the end of the class, she connected all student responses to summarise what they have learned in that and in previous lessons about the sensory system.

Time	Speaker	Line #	Talk	Code
00:00:00	Teacher (Charlotte)	1 2 3	Raise your hand if you learned something new from that paragraph. So, Wendy? Yeah	Teacher initiates – asking question – checking for understanding
00:08:99	Wendy	4	From confession of the sense we like it.	Student responds
00:11:49	Teacher (Charlotte)	5	Um, hmm, those. Very cool	Teacher gives feedback – encouraging feedback
		6	Something new?	Teacher repeats the question
00:14:48	Betsy	7	Certain parts went through your ear.	Student 2 responds
00:18:48	Teacher (Charlotte)	8 9	Yeah, that's cool. We would not know that, right? Good, Betsy	Teacher gives feedback – encouraging feedback
		10	What else?	Teacher repeats the question

While watching this case, the teacher (Charlotte) noticed that she did not connect students' ideas to every question 'to elevate learning' and she explained the reason for this is because of the phase of the lesson they were at:

> It would not necessarily [be] because of a time pressure; it would be because of the section of the lesson that I'm in. So, if I was introducing the new information, that's probably where I want that information to go out crystal clear, but in summary I just collect what students know already. (Charlotte, RTM#2, 4/8/2010)

In this case, the teacher made a decision between congruence (phase of the lesson) and high rigour (elevating learning). For the summary phase of the lesson, the teacher's goal was to bring together what students knew already rather than trying to make students' understanding 'crystal clear'.

In another case below, Sawyer (seventh/eighth-grade lead teacher) was questioning students' understanding of how to write a hypothesis in scientific research (see the timeline for the daily activity on 'Whole-class brainstorming on writing hypothesis and independent research' on 02/17/10 in Table 3). Here, Sawyer asked the same question, 'Come up with a hypothesis' or 'Give me a hypothesis' (lines 1, 2, 13, and 15) again and again to find the correct response, the correct way of formulating a hypothesis given the variables of eating chocolate cake versus vegetable soup and their impact on running.

Finally, the teacher left the cycle by formulating the hypothesis that he was seeking from the students.

Time	Speaker		Talk	Code
00:00:00	Sawyer (Teacher)	1 2	Chocolate for lunch as compared [to] a nice vegetable soup. Give me a hypothesis.	Teacher initiates – describing a case
00:09:55	Students	3	Ew … He was kidding … They don't …	
00:14:05	Sawyer (Teacher)	4 5 6 7 8 9 10	Impact how well, how fast you run? So, how does eating chocolate, chocolate, how does eating chocolate cake for lunch as compared to eating a nice, eating a nice vegetable soup – notice I said nice vegetable soup – impact how well you run? How fast you run? Now, come up with hypotheses – and I expect more than one or two hands. I'm gonna give some time cause I wanna pick somebody different. I am gonna pick Simon.	Teacher initiates– describing a case
00:49:05	Marisa	11	Maybe we eat some chocolate and – some chocolate.	Student responds
00:51:55	Sawyer (Teacher)	12	Okay.	Teacher ignores
		13	Give me a hypothesis.	Teacher repeats the question
00:53:05	Marisa	14	Um, sugar.	Student responds
00:55:55	Sawyer (Teacher)	15	Give me a hypothesis.	Teacher repeats the question
00:55:55	Marisa	16	Okay. Okay.	
00:57:54	Sawyer (Teacher)	17 18	I wish you listened [to] me. Here is the hypothesis. *(Points to the hypothesis sentence on the smart board.)*	Teacher repeats the question

The teacher here was trying to decide between cost (time) and responsiveness (to students' ideas). Although he wanted to get students' ideas on the hypotheses, he did not think he was getting any on-task students' responses that he could connect.

> You ask the question two or three times and, and, and no response and nothing close. Then, you ran out of time and give the response … . Looking at the models, I could try revoicing, asking the question differently. (Sawyer, RTM#2, 4/5/2010)

Teacher Sawyer also noticed that he could have used a different strategy (revoicing) to improve the IFA case.

In this section, we provided typical examples from three types of IFAs, which were apparent in our case: connected, non-connected, and repeating. These typical examples were selected among 191 video cases and showed that connected cycles were longer, whereas the non-connected cycles were shorter. We also recognised that although connected cycles included students' ideas, the students' authority in these dialogues was limited as their questions did not change the direction of the dialogue. Moreover, we were able to infer about teachers' decision-making processes through their reflections on their own practice.

Changes in teachers' conceptualisations of IFAs and challenges to effective implementation

Change in teachers' conceptualisation of IFA. Prior to watching video cases and readings about the academic literature on IFA, the teachers did not clearly see IFA as an assessment tool, but rather as a questioning strategy with an aim to evaluate the correctness of students' responses. At the beginning of the study, the effectiveness of these cycles was mainly evaluated by looking at the completeness of the cycles. However, the teachers' reflections on their view of the educational effectiveness of the cycles revealed other factors that need to be considered for evaluating the value of IFAs in classrooms.

Through video cases and the summary of articles, the teachers changed some of their initial conceptualisations on IFA. First, as opposed to seeing IFA only as 'questions that teachers ask on the fly', all four teachers started saying that 'IFA is really an assessment and assessment tool' and that such assessments are strongly connected to teachers' curriculum and lesson planning. Charlotte (fifth/sixth-grade teacher) said the following during the second meeting:

> What I do is review the old stuff, activating prior knowledge, tell them what I'm gonna teach them about today and, and introduce that topic. And then, through guided practice using that knowledge to gather as a group or in smaller groups, whatever [is] appropriate to do. That and then, um, independent practice of what that is. When your [students are] getting on there, and then wrap it up with a summary of what we have covered, which actually reconnects to step one, which was reviewing [the] prior lesson and then moving on. So, that's one thing that [the structure of curriculum], I think, is important to frame where my head is on through the questioning cycles. (Charlotte, RTM#2, 4/8/2010)

The second important change was related to the aims of IFA. When the teachers were asked to explain the aims of IFA after video cases and reading the literature, they added new aims to their previous list. When the teachers were asked for the aims of IFA at the third meeting, their new list included:

(1) Understanding individualised ideas/explanations of students;
(2) Improving students' critical thinking skills;
(3) Identifying the sources of students' ideas – are students' ideas from valid sources such as National Geographic websites and observations with university professors, or invalid sources such as 'my mom told so' and Wikipedia;
(4) Evaluating students' engagement to scientific reasoning;
(5) Communicating inferences during scientific investigations or experiments;
(6) Checking how well students learn from the teacher explanations; and
(7) Making decisions about the depth teachers could go or breadth that teachers could go to connect a particular concept to the broader scientific ideas.

The new aims increased the teachers' thinking about IFA and shows evidence that the teachers changed their ideas after watching IFA video cases, reading the academic literature, and interacting during RTMs. The change in the teachers' thinking related to different aims of IFA might also be the result of the teachers' involvement in academic discourse through reading the literature and connecting it to their practices.

Challenges to effective implementation. The findings of this study support previous research findings indicating a deficiency in subject matter knowledge and time limitations as challenges to effective implementations of IFA (Duschl, 2003; Furtak & Ruiz-Primo, 2008). The teachers in this study also discussed some challenges that have not been the focus of the previous study. One of these challenges is assuming 'authority of the knowledge' by some students – in other words, if certain students were seen as though all their ideas are 'correct' and they can approve or disapprove other students' ideas. This can create situations where one student dominates the IFA cycle and makes it harder for 'shy' students to express their ideas:

> I mean, you can have a bunch of shy kids, then, you know, where [it] may – that conversation may not happen or not naturally. You know, I think that's one thing – that's, I guess, the one drawback is maybe you do have, you know, those five or six kids that are really reluctant or just, you know, maybe not reluctant but they're just content, they just sit there and listen and, you know, they amused, they were entertaining, maybe they're in their own little world and, um, but it – you know, engaging those kids, you know, is sometimes a challenge because then you have kids that – Jason's – you know, have the hand up every time. And when he gets going, you know, and you really talked about trying to not let him dominate, not take that role as 'I know everything,' and so, like, Gareth in the one – Gareth started to give his explanation and looked at Jason for confirmation, like 'Right? What is – what I'm saying [is] correct, you know, Professor, right?' (Daniel, RTM#3, 5/14/2010)

According to Daniel, sometimes teachers should make the students feel that students might know more in-depth information: 'They can teach to their teachers about their research'; that is, they have the authority on the particular topic. Although Daniel sees giving authority to the students as a positive learning environment, he further states: 'Teachers may be challenged by the students who want to manage the conversations most of the time and those who are "shy" or have less interest in science' (Daniel, RTM#3, 5/14/2010).

In addition, Charlotte and Daniel also talked about the case where the limitless sources of scientific evidence have challenged them. In one of the lessons during the circulatory system unit (see the timeline in Table 3), Charlotte was using the circulatory system model to review how the system works. Students raised a question about blood being blue. Charlotte and Daniel wanted to say that blood is blue only in the figures, but then they asked students why they thought blood could be blue. This question led to responses as 'I saw it in the laboratory', 'My father told me so', 'I saw in the restaurant that the lobster had blue blood', and so forth. Then, Charlotte stopped that cycle after the responses. Charlotte said 'identification of these sources of scientific evidence was a challenge' and she explained the reason why she left the cycle:

> [A]ll I know is that that was risky because it perpetuated the knowledge in – kids actually accepted that as a fact. In my training, I have been told that if you learn something incorrectly, you have to learn it correctly over – learn it correctly twenty times to compensate for the one time that you learned it wrong. So, there are times that I'd rather children absorb the knowledge correctly. It's the very first time, so they don't have to unlearn the other things. Do you know what I mean?
>
> So, I would have cut off the blue thing so can you start going with it. So, I am not messing with that and I thought, 'We'll have to regroup for another day' and we did. I think we did have a clear explanation. (Charlotte, RTM#2, 4/08/2010)

Therefore, in the case where the teacher could not handle the resources, she preferred to stop that day and then get the response to the students after she carried out research on the colour of the blood.

This section introduced the challenges the four teachers of the study may have during the effective implementation of IFA. Time efficiency and subject matter knowledge were the challenges for science teachers in the previous studies on classroom-based assessments (Duschl, 2003; Furtak & Ruiz-Primo, 2008). Different from previous studies, external, standardised tests were not mentioned as a challenge in this study – this likely is a function of the project-based orientation of the charter school. Instead, all teachers agreed that effective implementation of classroom-integrated assessments helps students score higher in those tests. This finding also aligns with Ruiz-Primo and Furtak's (2007) study that provided statistical evidence for the effective use of IFA leading to better scores in summative assessments. This study also introduced two new challenges which were not the focus of previous studies on classroom assessments: authority of the knowledge and limitless sources of scientific evidence.

Discussion

This study explored IFAs, which are constructed during instructional dialogues among teachers and students, do not require any official record keeping, and aim to assist students' and teachers' learning. As stated in the findings of this study, it is through IFA that teachers, during their daily conversations with students, can identify the sources of students' ideas, evaluate students' engagement in scientific reasoning, determine the depth and breadth of knowledge they plan to teach, and help students to communicate the inferences during scientific observations and investigations.

By exploring IFA practices of four teachers in a local charter school, this study provided an in-depth analysis of these in-the-moment interactions and what teachers notice about their decision-making processes during these interactions. The local charter school in this study was unique in that it is smaller than the majority of public schools and their curriculum was sequenced as projects for the active involvement of students. Although in this unique case, we have seen all four teachers using more than traditional IRF/E cycles, the teachers were still challenged by two dimensions of practicality: cost and congruence to achieve rigour and responsiveness. The teachers had another distinctive case where they were co-teaching in the classrooms. This might be the reason why none of the teachers' comments focus on the dimension of practicality about instrumental sources such as activities, materials, and resources. During co-teaching, the teachers were able to help each other to find resources, tools, and information.

We focused on two major challenges related to the effective implementation of IFA. First, although there is a vast amount of research on in-the-moment interactions (e.g. Furtak, 2012; Thompson et al., 2016), teachers in this case study still have not noticed the importance of these interactions. Therefore, this study started responding to this challenge to help the teachers notice features of effective IFA cycles. As is evidenced from the third RTMs, we saw a change in how the teachers in this study conceptualise IFA after guided video reflections and readings. Second, previous studies have focused on how these IFAs can be effective, but mostly ignored how teachers see the effectiveness of such cycles in their practical worlds. This study explained the effectiveness of IFAs seen from the four teachers' eyes. Through addressing these challenges, we identified five discussion points relating to IFA, science education, and teacher learning about assessments: (a) the recognition of variations in the nature and use of IFAs, (b) the importance of building rigour in informal assessments through responsiveness, (c) the mediated nature of teacher learning about assessment in classrooms, (d) the role of student identity in classroom conversations, and (e) the changing metaphor for thinking about IFAs in classroom discourse.

First, IFAs varied in the nature and type of use across the 191 cases. Research in teacher education suggests that teachers' current practices should be examined before engaging teachers in any PD activity (Sato, 2003). For this reason, before engaging the teachers in discussions about IFA or reflections on their practices, we first examined the teachers' current practices of IFA within the culture of a small charter school where they practise co-teaching. An initial research-model of IFA (Figure 1) informed this analysis. The findings, from the analysis of the current practices, show that in the case of a small charter school where the curriculum is based on real-life projects and teachers practise co-teaching, IFAs are implemented in three ways in the classrooms: connected, non-connected, and repeating. In the video cases we selected, we realised that the connected cycles are longer in nature, whereas non-connected are shorter. These connected cycles offered the teachers the richest opportunity to be responsive to students' ideas and make in-the-moment adjustments. To do so, the teachers often needed to consider how to balance their practicality goals with being responsive to students, thus leading the teachers balance authority among the classroom members. Variation in the uses of authority across the cases identified how access to student thinking can be limited. Our cases showed that during some connected cycles, student authority in the dialogues was limited as they were strictly framed by teachers' questions.

The second finding of this study showed that any type of IFA can be effective or ineffective in achieving rigour and responsiveness. Although teachers can make suggestions for their future practice on improving their non-connected and repeating cycles, they did not provide suggestions to improve their connected cycles even when they saw the cycle was not responsive. When we looked at the teachers' dilemmas between dimensions of practicality and rigorous and responsive dialogues, we saw that they were challenged by creating a responsive dialogue, especially when time, background knowledge, social norms, and time were factors in completing the goals of a lesson. These factors play into the ways that teachers can come to develop a professional vision around assessments. In the case of IFAs, professional vision requires teachers to notice essential features of interactive, discourse events. As shown in these examples, a multitude of factors may influence how teachers come to recognise, interpret, respond, and evaluate student discourse. While rigour in evaluating student knowledge is important, achieving a sophisticated understanding of how scientific ideas are socially constructed requires being able to respond to the diverse discourse processes that occur with students while teaching science (Crawford, 2005). Responsiveness during IFAs is important because rigour in classroom activity does not exist without being responsive, as evidenced in the large-scale study conducted by Thompson et al. (2016). Thus, in developing learning experiences to improve professional vision around assessment in teaching, it is essential to provide practical tools for teachers on how to address students' cultural background and previous knowledge through classroom discourse.

Third, teacher learning was mediated by locally produced artefacts and other members in the local classroom community (Sezen-Barrie, Tran, McDonald, & Kelly, 2014). The findings from the last RTM indicated that after video-based professional PD, teachers' conceptualisations of IFAs evolved in recognising that IFAs are critical assessment tools that can help teachers gather in-the-moment feedback on sources of students' ideas, the ways to engage students in scientific investigations, what students made sense out of activities, and so on. This change in perspective was mediated by the locally generated and modified model for the IFAs (Figure 1) and by the video, episodes brought back into the interviews that served as PD conversations. The teachers became members of the community of researchers by contributing to the IFA model and viewing themselves on video. The RTMs, although initially designed to ascertain the teachers' views of the classroom events, came to serve as mediating artefacts for teacher learning about assessments constructed through classroom interactions. Thus, the video of the events and the nature of the classroom conversations made available material for interpretation and teacher learning. In this case, the learning about IFAs was derived from locally produced artefacts and members of the local classroom community. This suggests that attention to the uses of IFAs, and the development of professional vision around such embedded contextualised assessment, may be best derived from settings within the teachers' own experience, at least initially.

Fourth, while this study focused on IFAs, there is much happening in classroom conversations that can influence the potential of teachers' understandings and uses of IFAs to improve instruction. For example, while there were examples of teacher learning about students' ideas, and ways to respond, some challenges remained. One challenge involved one or only some students identifying themselves as science students. Studies of classroom discourse have recognised that choices students make to participate or identify themselves as knowing or not knowing are related to their respective identities as science students (Brown, 2006). In the classrooms studied here, some students had more confidence, as manifest in a willingness to participate in ways that sometimes limited other students' input about their own life experiences and understandings. Thus, while IFAs may be helpful in developing access to students' thinking, such thinking is only available when students are empowered to participate. Assessment conversations such as those in these classrooms make visible student knowledge, not only to teachers, but also to other students. In considering the uses of IFAs, teachers need to do so in ways that establish norms for participation that includes students less confident in their knowledge.

Fifth, this study was an attempt to improve teachers' conceptualisations on understanding the nature of IFA. Developing a professional vision about IFAs entails coding and highlighting instances found in the everyday experience of teaching. Highlighting involves labelling parts of the activity to make visible instances of significance in the complexity of experience. Coding involves recognising the values and significance of the event (McDonald, 2016). In this study, the teachers came to see IFA as a process of ongoing assessment and readjustment (metaphorically, a video of everyday life), rather than as a measure of achievement at a given time (a still shot photograph). By viewing classroom experience from the metaphor of video filming students' and their own learning processes, teachers can focus on different dimensions of science learning by assessing students' reasoning during scientific practices. Thus, like coding for the archaeologists in Goodwin's (1994) study, the teachers' changing metaphor provided themselves and others with a different way of seeing and understanding IFAs. The significance of the emerging view of assessment as ongoing, in the streams of everyday life, represents a conceptual change in thinking about how to understand and respond to students' ideas.

Suggestions for further studies

Even though our video-based PD helped teachers of one particular charter school conceptualise IFA cycles and understand the important roles of these cycles, this study was limited in the explore phase of bridging effectiveness and practicality of IFAs in one school culture. Therefore, we suggest further studies explore different cases and find ways to support teachers' use of effective IFA within the dimensions of practicality. First, more research needs to be done to understand how teachers can make IFAs more responsive to include *all* students when certain students assume the 'authority of the knowledge' in science classrooms. Researchers can explore if there will be an authority shift when teachers use discursive tools developed by researchers (such as in Tytler & Aranda, 2015). Furthermore, teachers need PD on how to utilise 'limitless sources of scientific evidence' rather than seeing students' use of these sources as 'risky'.

In our study, we found that teachers make in-the-moment decisions on their IFA cycles and we interpreted these in terms of the dimensions of practicality and effectiveness (i.e. achieving rigour and responsiveness). Teachers' decision-making during IFA cycles can also be explained by looking at their orientations towards science and science teaching (Schoenfeld, 2011). More studies should be conducted to see the influence of teachers' explanations of science knowledge construction and how they perceive their roles during this process. While reflecting on their decisions, teachers make suggestions to improve effectiveness for non-connected and repeating cycles. However, they do not provide suggestions even when prompted. Research in teacher education points out that within their complex, interactions teachers look at 'good enough' rather than the 'optimal choice' (Janssen et al., 2013). These good enough in-the-moment connected IFA cycles should be examined in further studies of teachers' improvement of these cases within the dimensions of practicality, that is, instrumentalism, congruency, and cost.

We also saw in our case study that time was a challenge to create more effective and longer IFA cycles. During the last three decades, there has been a push for reforms to change the traditional standards that are 'a mile wild and an inch deep' (Schmidt, McKnight, & Raizen, 1997). There is a move from covering the extensive amount of topics to teaching less but in greater depth in science, math, and literacy. In the U.S.A., the new standards (published, though not yet fully implemented in schools) are arranged as three-dimensional learning comprising science and engineering practices, cross-cutting ideas, and disciplinary core concepts (NGSS Lead States, 2013). By limiting the number of new ideas, these standards should allow more time to teachers to have more time (Stage, Asturias, Cheuk, Daro, & Hampton, 2013). This study was carried out before the implementation of these new science standards. A further study can look at time allocation in IFAs once the new standards are implemented. An examination of IFAs should be done in other countries with similar reform movements. Cultural variation in classroom norms and discourse practices poses important research questions and makes cross-cultural studies intriguing.

Comprehensive and practical models of IFA can be used as a guide for classroom implementation and PD of teachers. However, it is important to note that models should be used as a guide or draft, not as a script during the PD activities designed to improve classroom-based assessments. Teaching is a complex activity and the differences between individual students, teachers, and cultures of classrooms and schools can create different cases or different implementations of assessments. Therefore, the use of models as scripts may limit teachers' abilities to reflect on their practice and make effective changes. While teachers in this study were working on models of IFA, teachers or interns using this model for the development of their professional vision also need to know this is only an exemplar designed to help understand IFA and evaluate practice.

A future study can explore the details of mentor teachers' use of models to guide their interns.

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