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Abstract

The topic of teacher noticing has been refined in the mathematics education literature over the last 15 years. Researchers who study noticing have established a complex definition of this process, which encompasses how a teacher identifies, evaluates, and considers responding to a student's classroom contribution. They have also developed a variety of techniques to measure a teacher's capacity to engage in noticing and have documented how this capacity can change over time with certain interventions or experiences. Science education researchers have more recently begun studying noticing. Among other results, their efforts have yielded the concept of responsiveness to further the examination of a teacher's classroom actions in response to student contributions. This brief review article traces research in noticing from its origin in mathematics education to its current manifestation as responsiveness in science education. A synthesis of the research and suggestions for future studies are provided.

Keywords: noticing, responsiveness, responsive teaching

With an emphasis not simply on classroom activities, but also on student-centered instruction wherein teachers pay attention to individual student's ideas and questions and react accordingly, educational research in the past 15 years has used the term *noticing* for this facet of instruction; however, there is a refinement as to just what it means to notice in the context of this research. Contrary to the restricted commonplace definition of noticing, which generally only means perceiving or paying

attention to something, the concept of noticing in an instructional setting has come to take on a more complex meaning. Some authors have suggested consistent use of the term *teacher noticing* to distinguish from the more colloquial use of the verb *to notice* (Sherin, Jacobs, & Philipp, 2011). Berliner (1994) described two facets of pedagogical expertise that pertain to what has come to be called teacher noticing: "the accurate interpretation of cues and the recognition of patterns" (p. 177) and "*what* is attended to and *how* that information is interpreted" (p. 179, italics in original).

The study of teacher noticing first came to prominence in mathematics education research and continues to be an important topic to this day. Perhaps because of the similarity in approach to problem solving between the two fields, science education subsequently adopted the concept of teacher noticing and expanded it into research on teacher responsiveness. Teacher noticing and responsiveness are significant to these fields because of an ever-greater emphasis on student-centered instruction, which values student voice in evaluating a topic or determining a solution. In science education, for example, the *Next Generation Science Standards* (NGSS Lead States, 2013) emphasize eight science and engineering practices in which students should engage during their courses. Several practices, such as constructing explanations and engaging in argument from evidence, provide explicit opportunities for teachers to notice and respond to student ideas while students carry out these practices.

The purpose of this article is to review the research trajectories of teacher noticing and teacher responsiveness in the fields of mathematics and science education. Both terms are defined, and their origins briefly traced, in their respective fields. To provide the reader with an overview of how noticing and responsiveness are studied, this article summarizes the various methods that researchers have used to elicit and assess noticing and responsiveness. The subsequent section synthesizes recent research results in this field. Finally, following from the review of literature, specific criticisms and suggestions for future research are offered.

Conceptualizing Teacher Noticing and Responsiveness

In a study that first reified the concept of teacher noticing, van Es and Sherin (2002) proposed three key aspects of noticing: (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 (p. 573). This elaboration of teacher noticing formed the foundational conceptualization of the term, and has been cited frequently by fellow researchers (e.g., Huang & Li, 2012; Jacobs, Lamb, & Philipp, 2010; Russ & Luna, 2013) as the concept of noticing has expanded throughout mathematics education and been adapted by the field of science education.

Teacher Noticing

Stemming from the seminal paper by van Es and Sherin (2002), additional researchers subsequently added their own nuances to the concept of teacher noticing. For instance, Sherin et al. (2011) summarized the field of teacher noticing as asking three primary questions: "Where do teachers look, what do they see, and what sense do they make of what they see?" (p. 3). Indeed, in many studies teacher noticing is conceptualized as three distinct processes: noticing (that is, attending to student thinking), sense-making, and deciding how to respond. Similarly, Jacobs, Lamb, and Philipp (2010) divided teacher noticing into three interrelated skills: attending, interpreting, and deciding how to respond. They argued that when confronting student thinking, these three skills occur nearly simultaneously and subconsciously on the part of the teacher, forming an integrated teacher move.

Sherin, Russ, and Colestock (2011) simplified the concept of noticing even more by reflecting that researchers have generally characterized noticing as a process where each step depends on the previous one, therefore no step can be studied in isolation except the first. Under their conceptualization, noticing consists of perception, interpretation, and intended response. This tripartite division of noticing—with some variation of exactly where to draw the line between perceiving, interpreting/processing, and determining a response—has remained consistent in the mathematics education literature. These authors did not, however, include the teacher's actual response in their conceptualization of teacher noticing.

Teacher Responsiveness

More recent research within science education has moved beyond teachers' attention and noticing to focus on teacher responsiveness. Responding to student thinking is a result of in-the-moment formative assessment in any type of curriculum or lesson structure (Levin, Hammer,

Elby, & Coffey, 2013). As such, responsive teaching is distinct from the two broad categories of teacher activities that are generally envisioned as constituting science education: the traditional presentation of content and the more reformed method of facilitating students' construction of their own understanding (Levin, Grant, & Hammer, 2012). Teacher responsiveness is an active process of formatively assessing student understanding during instruction and consequently changing the way instruction proceeds.

Responsive teaching (Levin et al., 2012) has been particularly pursued and expanded through research based in science education. For example, in 2013, Levin, Hammer, Elby, and Coffey authored an influential practitioner's guide, *Becoming a Responsive Science Teacher: Focusing on Student Thinking in Secondary Science*. Responsive teaching in science education manifests itself in several actions on the part of the teacher that are a direct result of student classroom contributions. A responsive teacher first identifies students' expressed ideas concerning science content; the teacher then looks for connections between student ideas and the science discipline; and, finally, the teacher pursues these ideas for the purpose of fostering productive science discourse (Robertson, Atkins, Levin, & Richards, 2016).

Responsive teaching is therefore a continuation of teacher noticing in which a teacher's acknowledgment and resultant action surrounding student classroom input are emphasized. Noticing and responsiveness encapsulate a delimited set of teacher instructional practices, or teacher moves (Scherrer & Stein, 2013), in the classroom. For clarity and convenience, this review often simply refers to "noticing," though the intention is to refer to all aspects of a noticing event: recognition, evaluation, assessment of possible actions, and actual response to a student classroom contribution.

Eliciting Teacher Noticing and Responsiveness

Capturing a teacher's actions surrounding a noticing event—let alone assessing such actions—is a difficult task in educational research; moreover, the theoretical framing of teacher noticing and responsiveness lacks a significant discussion of what types of objects, events, phenomena, or other noticed elements warrant attention in research. Teacher noticing research began with using videos of classroom lessons being enacted; and, although the methods for evaluating noticing have ranged from student-written artifacts to letters between teachers and students, the

primary method used to characterize and evaluate participants' noticing capacity remains video recordings of classroom events.

Table 1 provides an overview of various resources that have been presented to participants. This review identifies three divisions of noticed elements. First are noticing artifacts produced independently by a student, potentially in a non-social situation (written problem solutions fall into this category). Second are video recordings of a context with which the teacher is unfamiliar (such as an unknown teacher's classroom). Third are videos of the participant's actual classroom, showing him- or herself in action during a previous lesson.

In a philosophical account of teacher noticing, Mason (2011) described three processes that surround noticing:

- preparing to notice (achieving the appropriate mental situation);
- reflecting on the past to become sensitized to noticing possibilities; and
- noticing in the moment, and thus reacting freely rather than habitually.

This account presupposes that noticing occurs in an authentic context, where the person engaging in noticing is familiar with the environment and the activity. As an extension of this idea, the concept of local noticing was introduced to refer specifically to noticing that occurs within a restricted timeframe—within minutes of the noticed event occurring—and is situated in the location of the event (Russ & Luna, 2013). Similarly, in-the-moment noticing occurs when a teacher is involved in an authentic instructional context and must identify, interpret, and decide how to respond to a student's input, face-to-face and in real time (Sherin et al., 2011).

Assessing Teacher Noticing and Responsiveness

Now that teacher noticing has been defined and the objects in which it can be manifested identified, the question arises as to how exactly to go about studying teacher noticing. Uniformly across the research literature, the method of eliciting teacher noticing has been to present participants with an opportunity for noticing to occur (see Table 1), and then either to ask them for a written response (often to specific prompts), record them as they think aloud through the noticing event, or conduct an interview using prompts related to noticing. With data gathered, researchers have had to develop a means of analyzing participant output to determine the extent, char-

acteristics, and quality of the noticing articulated by participants. In this regard, research on teacher noticing is a meta-noticing task: Researchers must perceive, evaluate, and decide how to articulate what participants are doing as these participants attend to, make sense of, and decide how to respond to student input during a noticing event. Researchers' methodologies and conceptualizations surrounding this process have been diverse.

After eliciting noticing, researchers have the task of evaluating this noticing. As calculating the total volume of noticing output would be too simplistic and likely not helpful, researchers have developed more sophisticated means of analyzing participant noticing. Table 2 provides a sample of the schemes that researchers have employed to categorize and evaluate noticing.

All reviewed studies had some means of characterizing the noticing that was elicited in the research design, and typically the evaluation scheme related to the tripartite definition of noticing (perceiving, evaluating, responding) discussed above. Talanquer, Tomanek, and Novodvorsky (2013) and Talnaquer, Bolger, and Tomanek (2015) divided noticing output into two general dimensions or realms. On the one hand, domain-neutral or task-general noticing relates to assessing student work without in-depth attention to student thinking. This type of noticing could consist of identifying learning objectives, describing student work, or simply marking work as right or wrong. On the other hand, domain-dependent or task-specific noticing involves evaluating student work in relation to how students grappled with the content of an issue. This more complicated type of noticing could include attending to specific ideas and inferring what the expression of those ideas could mean for student understanding and ability.

The end result of categorizing and evaluating elicited noticing is generally analysis of the characteristics of teachers' noticing capacity. In addition to characterizing such capacity, multiple studies have also investigated the difference in noticing capacity among various classes of teachers—with divisions typically occurring along the lines separating preservice teachers, novice teachers, and one or more class of experienced teachers (Huang & Li, 2012; Jacobs et al., 2010). Lastly, several studies investigated the impact of an intervention, such as educational coursework or a professional development experience (Levin & Richards, 2011; Scherrer & Stein, 2013). This impact has typically been measured using pre- and post-evaluations of noticing

capacity, but on rare occasions a control group was used (Barnhart & van Es, 2015; Kleinknecht & Gröschner, 2016).

Synthesis of Research Findings

The body of noticing literature has generated several consistent results. First, multiple studies revealed that novice teachers are not as proficient at noticing as their more experienced colleagues (Simpson & Haltiwanger, 2017; Star & Strickland, 2008). In many ways, this finding supports the notion of stages of teacher development (Fuller, 1969). Furthermore, studies have repeatedly demonstrated that interventions ranging from undergraduate coursework to professional development programs can improve the capacity for teachers to notice across time (Hawkins & Rogers, 2016; Mitchell & Marin, 2015; Sherin & Han, 2004; Star & Strickland, 2008).

These findings beg the question of how exactly a person's capability changes when this person is deemed to have acquired increased noticing capacity. Variations in noticing capacity have been described as differences in what individuals focus on (undeveloped noticing is associated with focusing on the teacher or on general classroom features; more advanced noticing involves focusing on student thoughts and problem solving) and as differences in how individuals interpret the work of classrooms (weak noticing capacity corresponds to discrete evaluations of work as right or wrong; more developed noticing probes into the thought behind an answer or other contribution) (Lee, 2016; Talanquer et al., 2013; Talanquer et al., 2015). Another view of noticing capacity is to identify three main areas along which noticing capacity develops: what is salient to teachers upon observing an instructional event, teachers' strategies for analysis of observed events, and the level of detail teachers provide in recounting observations (van Es, 2011).

Initially, the concepts of teacher noticing and responsiveness seem like a commonsense, foundational aspect of pedagogical practice, with implications in a variety of areas such as preservice teacher preparation, curriculum construction, and professional development. Yet, despite multiple research studies, it remains a challenge to establish not only what noticing is, but also how it can be identified, evaluated, and improved (Scheiner, 2016).

One limit of teacher noticing and responsiveness is that it is a demonstrated skill or capacity, not a form of teacher knowledge (Sherin et al., 2011). Nonetheless, the editors of the foundational volume on math-

ematics teacher noticing place the study of teacher noticing in the context of other significantly insightful constructs in the field of educational research, such as Shulman's 1987 conceptualization of pedagogical content knowledge (Sherin et al., 2011).

In summary, what follows is a list of clear conclusions about individuals' capacities for teacher noticing and the potential for its improvement:

- Noticing appears to occur along a trajectory and seems to be trainable.
- Beginning teachers' orientation to and interpretation of student input can evolve and improve with time and practice.
- What teachers attend to shapes what they consider and, ultimately, how they respond (there is a seriality to the subprocesses of noticing).
- Teacher noticing is highly impacted by teachers' beliefs and resources.
- Increased noticing capacity can bring about changed instructional practices.

Conclusion

Several methods of inquiry and conclusions about teacher noticing and responsiveness have been firmly established. As more research is conducted in this field, however, a stronger framework for defining, delineating, investigating, and assessing teacher noticing and responsiveness will be established; and, undoubtedly greater structure and deeper knowledge will be developed around these topics, resulting in improved classroom instruction and student-centered learning.

The Importance and Implications of Research in Teacher Noticing and Responsiveness

The concepts of teacher noticing and responsiveness fit sensibly within the current reform movement for education, which seeks to create a more student-centered classroom environment. A focus on the student requires a nimbleness in teachers that allows them to notice and respond to students' unique contributions to classroom activity as they unfold.

The implications of research in teacher noticing and responsiveness are most significant for teacher educators. There is nothing revolutionary behind the concepts of noticing and responsiveness, yet using these concepts to guide educational research brings focus to the types of practices that all teachers—and especially early career science and mathematics teachers—should

be enacting in their classrooms. Vagle (2009) wrote that "teachers are always, already perceiving in their teaching, through given situations" (p. 596). Emphasizing where to direct teacher perceptions and how to capitalize on them is at the heart of noticing and responsiveness. Teacher preparation and professional development programs should, therefore, articulate that recognizing student classroom contributions, evaluating this input, considering possible actions, and ultimately responding is a suite of teacher behaviors that can be trained and improved with deliberate effort. Several studies provide models for how to effect improved noticing capacity, with methods ranging from coursework (Amador, 2016; Barnhart & van Es, 2015; Levin & Richards, 2011) to professional learning communities (Hawkins & Rogers, 2016; Mitchell & Marin, 2015; Sherin & Han, 2004).

By paying attention to the specifics of student learning, teachers are more likely to enter into a self-evaluation of how their instructional choices affect student thoughts and actions. Ultimately, then, such attention can lead to the development of multiple responsive instructional strategies. Instead of simply repeating and then perhaps answering student questions during a lesson, teachers can begin analyzing the source and direction of student thought, eventually allowing teachers to see pedagogy from the perspective of various students. With teacher noticing and responsiveness opening up pedagogy as a multidirectional collaboration with numerous sources for gathering and interpreting data, teachers may ultimately refine and enact their craft as a manifestation of student-centered, inquiry-based learning—one in which teachers are the students, seeking to comprehend concepts and solve problems in the classroom.

Criticisms and Suggested Areas of Future Research

Given the extent to which the concept of teacher noticing and responsiveness has been clarified, there are still many questions that remain to be investigated. One area of inquiry is how the context in which a teacher works affords or constrains the enactment of noticing and responsiveness. For example, a teacher may exhibit an excellent capacity in one context, but noticing and responsiveness are not as apparent in another. What about a teacher's work environment enhances the capacity for noticing, as well as its development over time? Further research is needed on context sensitivity so as to establish how these student-centered practices are encouraged (or

discouraged). Similarly, there is a lack of research on the transferability of noticing—between working environments, classroom contexts, grade levels, topics, or even areas for which a teacher has a strong background versus ones for which he or she does not.

Although they may be framed using the concept of teacher noticing—and are included in this review to provide a full perspective—research studies that use only students' written responses as objects for studying noticing are really no different from studies of assessment. Much assessment research examines how teachers perceive, evaluate, and respond to student ideas (in the form of students' written responses to questions), but that does not make them studies of teacher noticing. Instead, teacher noticing should be based upon a real-time representation of a student's thoughts or questions—the pinnacle of which is in-the-moment or local noticing that several studies emphasize.

The teacher noticing literature has not been clear on distinguishing noticing that occurs as a result of elicitation by different objects—such as while reviewing a student artifact, watching pre-recorded video, or interacting with students individually or in a whole-class setting (see Table 1). A future study could evaluate whether an individual's noticing capacity varies between noticed objects and whether the variation, if any, is similar across individuals.

Of course, it is very difficult to study in-the-moment, local noticing in an authentic context as it unfolds; yet, this phenomenon is what researchers are referring to when they discuss a teacher's noticing practice. As a proxy for this type of noticing, classroom video is most frequently relied upon as a way to measure teachers' noticing capacity and as a way to train prospective and practicing teachers to develop their ability to notice. Video recording of classroom events is a relatively non-intrusive means of capturing objects for noticing. The nature and context of the recording (whether it was produced in a live social environment, whether it came from a familiar setting) must have an impact on the quality and extensiveness of noticing by the participant, but this effect has not been documented.

At its most restricted definition, teacher noticing is a practice that occurs in real time with actual students in an authentic setting. In this context, a teacher identifies a student's thinking in regards to a classroom learning situation, evaluates the thinking in light of the context, and decides on an appropriate response.

The capacity to notice can be evaluated by using objects and procedures that approximate this setting, but such studies are merely assessing noticing skill or capacity, and not observing noticing itself. Nonetheless, such studies are certainly important because having the capacity to notice is requisite for putting noticing into practice. Moving forward, research must clearly articulate how the object that elicits noticing and the context surrounding the noticing event relate to the teacher's actual instructional practice (and with it, the students' learning). Good teaching is a humanistic endeavor that calls for close attention to many details, environmental and interpersonal. Research into teacher noticing and responsiveness must not overlook the many forces at play in effective student-centered instruction.

Table 1

Examples of the Various Objects and Phenomena that Participants Used as Sources for Noticing

Object(s) serving as source of noticing	**Example studies**
letter exchanges (students responded to participant letters about math problems)	Crespo (2000)
student written answers to formative assessment probe	Talanquer, Bolger, & Schapelle (2011)
video clips of another teacher's class and samples of student written work (solving a math problem)	Jacobs, Lamb, & Philipp (2010); Goldsmith & Seago (2011)
U.S. TIMSS lesson videos	Star & Strickland (2008)
entire lesson of another teacher's class	Huang & Li (2012
recorded lesson clips from video club participant's classroom	Sherin & Han (2004)
stationary video of participant teacher's own instruction	van Es & Sherin (2002); Barnhardt & van Es (2015)
point-of-view video of participant's own instruction	Russ & Luna (2013)

Table 2

Categories of the Various Occurrences or Characteristics that Researchers Expected Their Participants to Notice by Study that Employed Characterization Scheme

Evaluation characteristics for noticing	**Source study**
1. classroom environment 2. classroom management 3. tasks 4. mathematical content 5. communication	Star & Strickland (2008)
1. students' strategies 2. students' understanding 3. determining a response	Jacobs, Lamb, & Phillip (2010)
1. task-general elements 2. task-specific elements	Talanquer, Tomanek, & Novodvorsky (2013)
1. domain-neutral aspects 2. domain-dependent aspects	Talanquer, Bolger, & Tomanek (2015)

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