# Teaching Analytics: A Multi-layer Analysis of Teacher Noticing to Support Teaching Practice

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**Abstract:** This paper, as part of a larger ongoing study, presents the use of a multi-layer approach to analyzing teacher noticing for the improvement of teaching practices. Situated in the field of teaching analytics, the use of multimodal sensors and analytics, especially for teacher noticing research, has provided affordances to discover deep insights for improving teaching practices. We collected data from a case study of one teacher over three lessons of science teaching in a secondary school. Multimodal sensors including an eye-tracking device, a microphone, and multiple video cameras were deployed in a classroom. The various sources of data were integrated and a multi-layer analysis was performed to uncover insights into the teaching practice. The findings show that a novice teacher in our case study was able to attend to events in her classroom, with some interpretations and sense-making of the events; some necessary actions were taken based on the teacher's analysis but in some instances, necessary action was found to be lacking. Prior knowledge and the wealth of experiences or the lack thereof, together with visual cues in the environment, can affect the decision of novice teachers in executing certain actions in a classroom.

**Keywords:** Teacher noticing, teaching analytics, multi-layer analysis, teaching practice

## 1. Introduction

Research for improving teaching and learning processes in science education are prevalent in various forms. For example, it can exist as interventions to improve teachers' practice (Kiemer, Gröschner, Pehmer, & Seidel, 2015), or in more recent times, developed as part of online tools (Kuosa et al., 2016) to enhance visualization and innovative equipment for acquiring data (e.g., eye-tracking device in eye movement research by Jarodzka, Holmqvist, & Gruber, 2017). These research help to gather insights into the improvement of teaching and learning, whether in face-to-face situations or within online learning environments. Although educational data mining and analytical algorithms are automating processes and aiding processes to be easily implemented, there is still a need to make learning activities visible, so that both teachers and students can develop skills in monitoring their own learning and see directly how invested efforts can improve learning (Bienkowski, Feng, & Means, 2012). The learning analytics approach has thus been applied to further these efforts in understanding teaching and learning processes, often through visualizations, methods, and digital tools that measure, collect, analyze and report data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs (SOLAR, 2011).

Teaching-oriented learning analytics, also known as "Teaching Analytics", refers to an approach that supports teaching practice through the use of analytics (Vatrapu, Teplovs, Fujita, & Bull, 2011) and improve educational designs prior to the delivery (Sergis & Sampson, 2017). This form of analytics contains similar analytical processes that follow closely that of learning analytics processes, beginning with the gathering and analysis of data, followed by interventions to seek newer understanding of classroom situations. As a result, teaching analytics projects also tend to follow the theoretically-grounded Learning Analytics Cycle (Clow, 2012), which conceptualizes learning analytics work as four linked aspects: learners (aspect 1) generate data (aspect 2), that is used to produce metrics, analytics or visualizations (aspect 3), with key emphasis on 'closing the loop' by feeding back this product to learners through one or more interventions (aspect 4). However, as pointed out by Prieto, Sharma, Dillenbourg, and Jesús (2016), due to the abundance of online trace data generated on digital platforms and the ease of implementing triggers or interventions in an online environment, teaching

analytics have become mostly focused on online or blended learning situations and often lack the crucial step of supporting teaching interventions based on learning analytics insights. In face-to-face situations such as classroom-based instruction, classroom data is captured in the forms of video data, field observations and discourse data, which may be further analyzed to aid the crafting of interventions to support teaching. One main challenge is how can the identification of teaching practices during lessons be improved and the insights be applied to support teaching practices?

This paper presents a multi-layer approach to analyzing teacher noticing. We collected data, from a case study of one teacher over three lessons of science teaching with secondary school students, using multimodal sensors, including an eye-tracking device, a microphone, and multiple video cameras around a classroom. The various sources of data are integrated into a single data set before a multi-layer analysis is applied to generate insights that could be drawn from each level of the analytical lens.


## 2. Literature and Related Work

### 2.1 Teacher Noticing

Noticing is a natural part of human sense-making and can aid interpretation based on one's orientations and goals. Noticing entailed by teaching, thus also referred to as teacher noticing, is specialized to its purposes, such as noticing things that are central not to personal goals, but to professional ones (Sherin, Jacobs, & Philipp, 2011). Therein lies a crucial and often overlooked factor that has to be considered in studies that involve teacher noticing, which is the contrast between experienced and newly-trained observers in noticing and interpreting events that happened in classrooms. For example, a disruptive student in class might use unruly behavior to hide the insecurity of approaching a difficult subject, thus affecting the progress of the lesson. A novice teacher might be unable to handle the situation and choose to ignore the situation over time, but an experienced teacher will pick up on visual cues and question the student to provide further support.

Early research focused on how teacher noticing affects pre-service teachers' abilities to attend to student thinking and learning in lessons (e.g., Levin, Hammer, & Coffey, 2009), or on the use of evidence to support claims of teaching effectiveness (e.g., Santagata & Yeh, 2014). There are currently some but limited attention paid to the use of multimodal sensors to capture and provide pre-service, newly-trained, or novice teachers with more insights to support their teaching practice (Prieto et al, 2016). In general, literature (Jacobs, Lamb, & Philipp, 2010; Sherin et al., 2011) have shown that teacher noticing involves three processes, namely, 1) attending to particular events in an instructional setting, 2) interpretation and making sense of the events in the instructional setting, and 3) deciding necessary actions based on the analysis. In this paper, a wearable eye-tracking device was used to record, across multiple lessons of instruction, how a novice teacher attended to classroom events, made sense and interpreted the events, and eventually took action.

### 2.2 The Affordance of Technology and Eye-tracking Device to Understand Teacher Noticing

A large number of technological tools exist to aid teachers in analyzing student-related aspects, ranging from visualizations of student progress in activities (Phillips & Popovic, 2012) to devices that alert and guide teachers to students who need help (Alavi & Dillenbourg, 2012). Recent studies (Matuk, Linn, & Eylon, 2015) tapped on the features of technology to afford customizations that support individualized guidance to teachers and reduced the need for teachers to dynamically adapt to students. The use of eye-tracking technology is currently more pervasive due to advancements of technology and as more researchers take an interest in investigating teachers' professional vision (Wolff, Jarodzka, Bogert, & Boshuizen, 2016; Stickler, Smith, Shi, Caws, & Hamel, 2016). Although eye tracking is an invaluable tool to investigate the execution of professional tasks via eye movements (Jarodzka et al., 2017), our take on the use of eye-tracking technology coincides with what research in other fields such as medicine have reported (Kok & Jarodzka, 2017): that even though eye movements reflect cognitive processes, these cognitive processes cannot be directly inferred from eye-tracking data. Therefore, for us to interpret eye-tracking data properly and frame it within a teaching analytics context, this paper incorporated the use of multiple recording devices to collect data for analysis with eye-tracking data

using a multi-layer analysis. The interpretation of eye-tracking data is further supported by evidence obtained through reflective dialogues with teachers.

## 2.3 Multimodal Learning Analytics (MMLA)

There are opportunities and challenges in using multimodal learning analytics (MMLA; Ochoa, Worsley, Chiluiza, & Luz, 2014; Worsley, 2016), a nascent subfield in learning analytics. As an emergent trend of capturing, modeling, and interpreting multimodal interactions that occur in both digital and face-to-face learning environments, a variety of data sources can be used to complement common digital analyses. However, given a large amount of multimodal data that could be obtained from various data sources, there remains a substantial amount of pre-analysis and conceptual considerations for data fusion. The variety of natural rich modalities may be redundant in some circumstances. In this study, a combination or fusion of modalities is designed to give more affordance to analysts and provide deeper insights into supporting teaching practice.

Prieto et al. (2016) cautioned that using multiple layers of analysis might not always provide better results, sometimes such methods only lead to marginal gains. In our case study, we consciously leverage different affordances of each modality so that newer or previously obscure insights may be discovered when MMLA is used with a multi-layer analysis to interpret and make sense of the data, based on the provided data in each layer of analysis.

## 3. Methods

### 3.1 Multimodal Data Collection

Our case study uses multimodal data from three sources ─ an eye-tracking device that is worn by the teacher during the lesson, a microphone attached close to the teacher's mouth, and two cameras around the classroom (placed at the front and back of the classroom) to capture activities within the classroom. To minimalize the influence of cameras on the behavior and performance of both teachers and students, we oriented the teacher with the equipment and explained the study's non-assessable objectives before the start of the lesson. A pre-lesson briefing was then conducted by the teacher to inform students of the nature of the equipment and that the video recordings will neither impact nor be used to assess their behaviors during instruction. Participants have the right to not participate or withdraw from the study at any time and this action will not result in punitive measures or loss of benefits.

In this paper, the outputs from the various recording devices can be individually collected and analyzed as part of a layer of analysis that is shown in Table 1, or if needed, different combinations of multimodal data can also be brought together for analysis. Video footages from the two cameras placed around the classroom are collectively referred to as "video data". Audio data recorded through the microphone was transcribed and referred to as "discourse data". The eye-tracking device was accessed through a D-Lab software platform in order to download a "Point-of-View" (POV) video footage and a list of gaze point coordinates, which are collectively referred to as the "eye-tracking data".

### 3.2 Multi-layer Analysis and Measures

There are three layers of analysis. We named the layers of analysis as shown in Table 1, mainly for the ease of reference in this paper. The multi-layer analysis begins with a basic analysis that scrutinizes student activity in a classroom, based on what is observed visually from the two sources of video footage. This is followed by an intermediate analysis based on a combination of the video data and a transcript consisting mainly of teacher's instructions interjected with some student interactions. The third final layer of analysis is based on data from all modalities in the case study, including video data, a transcript of discourse, and eye-tracking data (POV video and a list of gaze points).

Table 1

*Analytic components of each layer in the multi-layer analysis*

| Layers of Analyses (starting from top to bottom) | Analytic components in each layer | | |
|---|---|---|---|
| Basic Layer | Video Data | | |
| Intermediate Layer | Video Data | Discourse Data | |
| Final Layer | Video Data | Discourse Data | Eye-tracking Data |

Similar to the processes that were mentioned in the literature, within each layer of analysis, there are three interrelated and cyclical processes that we examined in our case study. We focus on three aspects: 1) whether the teacher was attending to particular events in an instructional setting, 2) how the teacher interpret and make sense of the events in the instructional setting, and 3) take the necessary and appropriate actions based on the teacher's analysis.

To analyze the first aspect, we focus on the location that the teacher chose to look at, which was determined using the POV video footage (see Figure 1). The gaze point was plotted onto the video, using the list of coordinates obtained from the eye-tracking device.
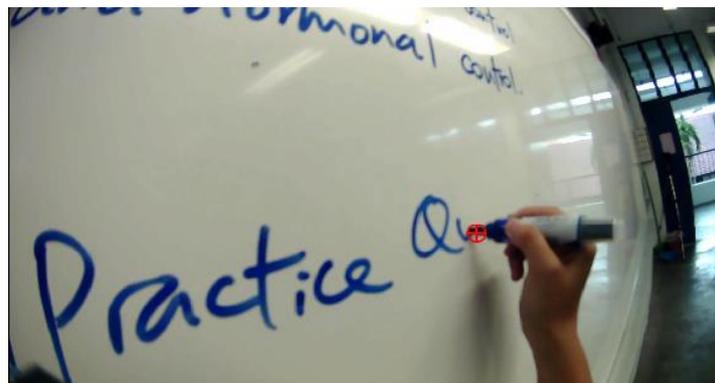


*Figure 1.* Screenshot from a Point-of-View (POV) video when the teacher was writing on a whiteboard. The gaze point is represented by a red crosshair-like symbol.

After the data were processed and transcribed, we engaged the teacher in reflective dialogues to understand the teacher's interpretation of events, how the teacher made sense of the events, and on actions that took place after the analysis has occurred. In the following subsections, we describe the processing and integration of different data sources in the various layers of analyses.

### 3.2.1 Using video data – Basic layer of analysis

Two video cameras were used to capture the teacher's practices and student activities during lessons in a classroom setting. The two cameras were placed at the front and back of the classroom to provide overlapping fields of vision and to ensure that most, if not all of the classroom activities, were captured for analysis. Based on the visual data, two researchers noted and concurred the general direction and any specific objects or subjects (students in this case study) that the teacher was looking at or interacting with during the period of analysis. In this layer of analysis, we are solely interested in the insights from video analysis of movements and physical positioning of the teacher. We also expect the subsequent intermediate layer of analysis to provide clearer insights into a teacher's practice and conversations with students.

### 3.2.2 Using video and discourse data – Intermediate layer of analysis

The audio conversations between the teacher and students were recorded using a microphone that was attached close to the teacher's mouth. The audio recording was then synchronized with the video data. The audio recording was transcribed and actions that were observed from the video data were integrated into the transcript, thus forming a more detailed description of the teacher's instructions and

interactions with the students in the classroom. This transcript was then used to interpret the teacher's actions.

### 3.2.3 Using video, discourse, and eye-tracking data – Final layer of analysis

Using the D-Lab software, we were able to record and export eye-tracking data, consisting of the POV video and a list of gaze points. These data allowed us to interpolate and determine areas that the teacher was looking at any point in time during the lesson, by focusing on significant gazes that hover around or fixate on a subject or object in the classroom environment for more than two seconds. Together with the other sources of data, we interpreted the teacher's noticing habits and interactions with the students, alongside any subsequent actions that took place.

### 3.3 Reflective dialogue for further understanding and validation

Recordings of what the teacher pay attention to during classroom instructions were used during reflective dialogues as concrete reference points for recall and discussion. We relied on Video-Stimulated Recall (VSR; Sturtz & Hessberg, 2012), that is, after the teacher had watched video-recorded segments of classroom instruction, we conducted a reflection discussion with the teacher. Through this method, we gathered insights into the interpretation and sense-making processes that the teacher demonstrated at the time of events in the instructional setting, along with the thought process on the necessary actions that were taken based on the teacher's analysis. Eventually, from our observations, we would also be able to delve deeper into the understanding of the unarticulated thinking and decision-making processes that effective teachers engage in while conducting instruction (Martinelle, 2018).

## 4. Case Study

### 4.1 Dataset and Settings

The data for our study was collected based on the teacher's availability and scheduled lessons in a secondary school. Overall, a total of three lessons (30-60 minutes) were collected, totaling over two hours' worth of multimodal data. The teacher is considered a beginning (novice) teacher in the local context, with less than three years of experience. Three classes of between 28 to 34 students attended each lesson in which the teacher wore a wearable eye-tracking device with an attached lapel microphone. A researcher helped to set up two cameras to capture students' activities from the front and back of the classroom. The recorded lessons began with the students greeting the teacher and ended when the teacher dismissed the class. All three lessons had a similar lesson plan to teach science and are mainly teacher-based instruction, interspersed with some group work and individual in-class assignments.

The teacher has a free reign on their actions with no restrictions other than to avoid touching the eye-tracking device in order to retain a high accuracy of measurements obtained through an initial calibration and setup process. An example of the teacher during the lesson is shown in Figure 2, with some identities whited out for anonymity.

*Figure 2.* Back view from one of the cameras capturing teacher-based instruction in a classroom. The teacher was wearing an eye-tracking device that drew power from a backpack.

## 4.2 Choice of Events for Analysis

Considering the amount of multimodal data collected, we initially browsed through the collective video data to identify several events that were interesting for investigations and might contain some insights that are only discernible with the multi-layer analysis. In this paper, we presented two such events that stood out and we further probed the teacher during the reflective dialogue for understanding and validation of the events and actions that were revealed in the video data.

## 4.3 Findings and Discussion

In this section, we first present the summarized findings from our multi-layer analyses in the form of a table, followed by our interpretations from each layer of analysis. Insights obtained from the reflective dialogue were then used to corroborate our findings. The first event occurred at the early stages of a lesson when the teacher was awaiting students to settle into the classroom.

Table 2

*Findings from a multi-layer analysis of the first event*

| Layer of Analysis | Analyses and Interpretations |
|---|---|
| Basic Layer – Video Analysis | • The teacher monitored students entering the classroom and gesticulated at an incoming student (Student C) who stopped at the entrance, seemingly due to a seating issue. Student C proceeded to sit at an empty space and the teacher proceeded with instructions involving content presented on a screen. |
| Intermediate Layer – Video and discourse analyses | • The teacher was apparently checking with Student C, who was distracted by another Student J who was sitting at Student C's original seat. The teacher then probed the reason for the displacement of Student C and the matter was settled amicably when Student C proceeded to sit at a different seat.<br>• Discourse analysis showed that the teacher first emphasized the lack of time and was in a hurry to start her lesson immediately before she observed the incoming Student C. The students involved in the debacle were left to their own devices to settle the seating issue as the teacher did not provide any instructions to resolve the issue or offer any solutions to the students. Student C eventually decided to sit at an empty seat to end the stalemate. |
| Final Layer – Video, discourse, and eye-tracking analyses | • In addition to previous analyses and observations, when students were entering the classroom, the teacher's gaze was on the incoming students, but it stopped and shifted to Student C, who suddenly stopped at the doorway. The teacher's gaze then tracked the direction of the seat |

that Student C was looking at, before focusing back to Student C. The problem was then apparent to the teacher, as she asked Student C "who took your seat" and proceeded to scan through the neighboring students to check on their responses to the question. The teacher then recalled from previous experiences that another Student J has taken Student C's seat and queried Student J. During this interaction, the teacher's gaze was alternating between Student C and Student J.

- After getting a vague clarification from Student J, Student C had already settled in a new seat and the teacher saw there were no remaining students who were standing and decided to end the issue. The teacher momentarily paused for a moment with her gaze fixated on a blank space between students, before proceeding to explain the content on the screen.

From the multi-layer analyses in Table 2, we noted that the teacher attempted to get students to settle into the class before she could begin covering the required content within a limited amount of time. During the reflective dialogue, we showed the teacher a video snippet of the event and asked her for the most significant thing that she can recall about what happened. The teacher replied that she was surprised that Student J and her friend beside her were sitting in Student's C seat in the middle of the classroom, rather than at the side of the classroom. This event unsettled her slightly and she mentioned that Student J and her friend were known to be unenthusiastic students, and as such, she should have focused attention more on them. Therefore, from this event, it was apparent that the teacher was swift in detecting visual cues within the classroom, but have difficulties handling unexpected students' behaviors. Although she was undeterred by the turn of events that she did not previously encounter, the teacher's composure was affected before the lesson even started. The reflective dialogue with the teacher also revealed that there was prior knowledge of certain students that might have caused inaction on the teacher's part. The next event took place in the middle of a lesson when the teacher was instructing using content from a presentation slide.

Table 3

*Findings from a multi-layer analysis of the second event*

| Layer of Analysis | Analyses and Interpretations |
|---|---|
| Basic Layer – Video Analysis | - The teacher was instructing using presentation slides, with frequent head turning movements at the slide's content and gesticulating to better explain a structure found within a leaf. She gave attention to the students seated at the front by looking at them, but there was no further engagement with any student. Several front row students were staring blankly with heads resting on their hands and yawning at several instances. The students' general behaviors reflect disinterest and boredom during this part of the lesson. |
| Intermediate Layer – Video and discourse analyses | - The teacher was explaining the concept of photosynthetic cells in a plant, using vertical hand gestures to simulate the efficient packing of palisade mesophyll cells.<br>- Discourse analysis also showed that there were multiple instances where the phrase "maximize the rate of photosynthesis" was overly emphasized and constantly appeared in a sequence of sentences.<br>- Similar to the first event, the teacher was rushing through the content and therefore, gave minimal wait times after questions were posed for students to think, resulting in students giving garbled or no response. This also resulted in some students preferring to copy content from the presentation slides onto their textbooks rather than pay attention to the teacher. The teacher noticed this trend and admonished the students, asking the students not to copy, as she would provide notes at a later time, but students would still need to fill in the blanks in the notes. |

| Final Layer – Video, discourse, and eye-tracking analyses | • When explaining the content from the slides, the teacher was making several glances from the students and back to the screen to refer to some technical terms, a possible indication that she was unsure of the instructed content. <br>• The teacher repeatedly emphasized "maximum rate of photosynthesis", and her glance was not on any object, but at a space right above the students' heads that hovered for a significant period of time. <br>• There was a lack of engagement and eye contact with students during this event, possibly leading students to feel bored and uninterested, with some students preferring to copy notes into their textbooks instead of listening to the teacher. |
|---|---|

The multi-layer analyses in Table 3 show that when the teacher was teaching, she was also having issues in engaging and maintaining this engagement with the students. During the reflective dialogue, we showed the teacher a video snippet of this event and similarly asked her for the most significant thing that she can recall about the event. The teacher explained that during instruction, she was often thinking while speaking and did this quite often during lessons, as she tried to find the appropriate words to use during the lessons, followed by consideration of necessary actions to take. As such, she often did not look at the students and hence had little situational awareness of students and their activities while she was speaking. This piece of information corroborates with the evidence in our study that shows the teacher seemed to be distracted during the instruction, as she gazed at blank spaces above students' heads while instructing and thinking. As the teacher was also thinking while instructing, she might have not been paying attention to her own talk as she repeatedly emphasized a series of phrases, with little recollection of what she just spoke.

With this in mind, the teacher further added that she could hardly observe or interpret the level of students' understanding during lessons, or whether the students were engaged with the topic at hand. This means that the teacher most probably did not notice the students' general level of disinterest and boredom during lessons. She also acknowledged that she found it challenging to process her observations and was unable to think sufficiently and react in a timely manner to unexpected events, which might have led to inaction as observed in the first event (seating issue). Surprisingly, the teacher mentioned that she noticed this trait in herself when she was supervising the hockey team as well.

We interpreted the teacher's response as a way of how the teacher tried to identify her areas for improvement in teaching and to circumvent her limitations to adapt to the situation. The use of multimodal sensors and multi-layer analysis helped to identify certain behaviors of concern during teaching, which the teacher was then able to relate to certain shortcomings in her teaching practice. After the reflective dialogue, the teacher was able to seek help from educational specialists in modifying her teaching practice to suit her needs. The lecture method of instruction chosen by the teacher was a problem for her as she was unable to process information and think sufficiently fast on her feet. It was then suggested that she could explore choosing strategies that depended more on students working in groups to learn. Using this strategy, the teacher would do less talking and she can then focus on making sense of students' learning and interactions.

From the various analyses using our multi-layer approach, the findings from the two events helped to affirm that prior knowledge and experiences or the lack thereof, and visual cues in the environment could affect the decision of novice teachers in executing certain actions in a classroom, similar to learners in other studies (e.g., Luo, Koszalka, & Zuo, 2016). In the first event, the appearance of a visual cue prompted her to stop her current activity and shift her gaze to investigate the cued event, much like how visual cues are an effective tool for grabbing attention (Jamet, Gavota, & Quaireau, 2008). Such swift responses can, however, be detrimental for the teacher when dealing with constant distractions in a classroom. It might be advisable for her as a novice teacher to learn from expert teachers, as shown in other studies (Carter, Cushing, Sabers, Stein, & Berliner, 1988), to weigh the importance and form connections between pieces of information, so as to better represent management and instructional situations as meaningful problems that can eventually be solved.

Overall, our multi-layer analysis can provide users with combinations of analyses that provide different types of information and different levels of details for improvement. From the various layers of analyses, users can expect to obtain a certain fidelity of data insights. A summary of the insights that a teacher might obtain from the respective layers of the multi-layer analysis is presented in Table 4.

Table 4

*A summary of insights from the respective layers of analysis*

| Layer of Analysis | Insights |
|---|---|
| Basic Layer – Video Analysis | Video analysis can provide a basic understanding of events and actions that took place in the video, but without specific attention to detail. |
| Intermediate Layer – Video and discourse analyses | The additional discourse analysis provides more details regarding the events, follow-up actions and possible reasons for doing so. There are clearer indications from the discourse that signal the intention of actions that the teacher may or may not take. |
| Final Layer – Video, discourse, and eye-tracking analyses | Eye-tracking data can provide clearer statistical and visual indications, such as the number of glances and noticing patterns, of why certain actions took place and if any preceding factors (such as subjects or objects) were considered before eventual actions were taken by the teacher. |

## 5. Conclusion

This study is part of a larger ongoing study that investigates the effects of using a multi-layer analysis for explaining and improving teaching practice. Situated in the field of teaching analytics, the use of multimodal sensors and analytics, especially for teacher noticing, has provided affordances to discover insights for supporting teaching practice.

In essence, we noted the teacher attending to particular events, with some interpretations and sense-making of the events, followed by the taking or lack of necessary actions that were taken based on the teacher's analysis. Our basic analysis was able to provide an elementary understanding of the setting and actions that occurred during the event, while the discourse analysis in the intermediate analysis provided more details on possible reasons as to why certain actions took place, with some insights into the teacher's possible intention in conducting follow-up actions. In the final analysis, the teacher's intent in making certain actions were noticeably clearer, as we noted in the first event, where the teacher noticed visual cues in a logical and sequential manner (such as following Student C's gaze to the seat and scanning of neighboring students) that allowed her to better decide the best course of response. In the second event, the multi-layer analysis provided a similar sequence of explanations that identified the teacher's need to change her teaching practice in order to adapt to her students' needs.

Moving forward, we are in the midst of recording data from teachers with different experiences and will apply this multi-layer approach to discover deep insights for improving teaching practices.

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