SUCCESSFUL IMPELEMENTATION OF EXPLICIT ATTENTION TO CONCEPTS (EAC) IN MIDDLE SCHOOL CLASSROOMS

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This study addresses the need to better describe instructional strategies used by middle grades mathematics teachers. After coding 177 videos of grades 6-8 mathematics instruction for indications of effective instructional practices, we further analyzed 8 of the highly scored videos with specific attention to teachers' implementation of strategies associated with Explicit Attention to Concepts (EAC) (Champion et al., 2020). We found that these effective teachers of mathematics tended to enact EAC by using a preferred strategy more predominantly than others, though all teachers used at least two EAC strategies during a lesson. Additionally, most participants in our study used an Initiate, Response, Evaluate (IRE) format (Mehan, 1979) when enacting EAC. We illustrate examples of their instruction with vignettes.

Keywords: Mathematical Representations, Instructional Activities and Practices, Middle School Education, Classroom Discourse

The implementation of instructional practices that help improve student achievement in mathematics has proven to be nuanced and difficult (Hill et al., 2005; Stein, et al., 2008). In a synthesis of studies, Hiebert and Grouws (2007) identified Explicit Attention to Concepts (EAC) and Students Opportunities to Struggle (SOS) as instructional approaches which were effective in increasing student mathematics achievement. Stein et al. (2017) found that students whose teachers' classroom instruction exhibited greater use of EAC and SOS had higher student math achievement gains than their peers on assessments that measured conceptual understanding and on assessments that measured procedural skills efficiency. These findings have been confirmed since 2007 (Flores et al., 2015; Fyfe et al., 2014; Kazemi & Stipek, 2009; Ng & Lee, 2009; Paliwal & Baroody, 2020; Stein, et al., 2017; Wilson et al., 2019). EAC and SOS are very general clusters of instructional strategies, though, and we need nuanced analysis of how teachers in particular contexts implement more specific instructional strategies to better design learning environments focused on student learning.

Theoretical Framework

Hiebert and Grouws (2007) focused on the importance of the presence of both EAC and SOS in mathematics classrooms for students to learn both procedural and conceptual mathematics. Considerable attention has been given as of late to SOS (Esmonde & Langer-Osuna, 2013; Jackson et al., 2013; Warshauer, 2015) and less attention has been given to EAC. For this study, we will focus on EAC. Hiebert and Grouws (2007) described what they mean by EAC with this statement: "By attending to concepts we mean treating mathematical connections in an explicit and public way" (p. 383). Hiebert and Grouws (2007) cited multiple studies spanning 50 years that indicated procedural and conceptual understanding of procedures is learned and retained better by students who learned from teachers who focused on both mathematical concepts and made connections between the procedure and conceptual understanding behind the procedure. Examples of EAC include attending to mathematical concepts, making connections among multiple representations, making connections across

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solution strategies, and reminding students of the main concept of the lesson and how it fits into a sequence of lessons.

Given the challenge of implementing instructional practices that help improve student achievement in mathematics (Hill et al., 2005), it is important to capture the scope and subtleties of effective mathematics instruction in order to better design learning environments that take student learning into account. Champion et al. (2020) created an EAC and SOS practice guide (see Figure 1; Champion et al., 2020) to add clarity and make EAC more actionable for teachers (while the practice guide addresses both SOS and EAC, our analysis focuses on EAC). The framework describes three overarching features derived from Hiebert and Grouws (2007) definition. Specifically**,** EAC is present in instruction that features: (a) a focus on mathematical concepts, (b) concepts that are made explicit and public, and (c) connections being emphasized between concepts and representations of ideas.

To make the EAC construct more actionable, the framework provides practical strategies that teachers could use to actualize the characteristics of EAC in their classrooms, each with two examples. Again, these strategies are identified from Hiebert and Grouws (2007) description of EAC. The Strategies for EAC are: (1) Specifically connecting to more than one representation of an idea, (2) Noting ways that different solution strategies are similar or different, (3) Discussing the mathematical reasoning that underlies a procedure, and (4) Pointing to a main idea in a lesson and how it fits into a bigger picture. Examples of each strategy are labeled A and B under each strategy (see Figure 1; Champion et al., 2020).

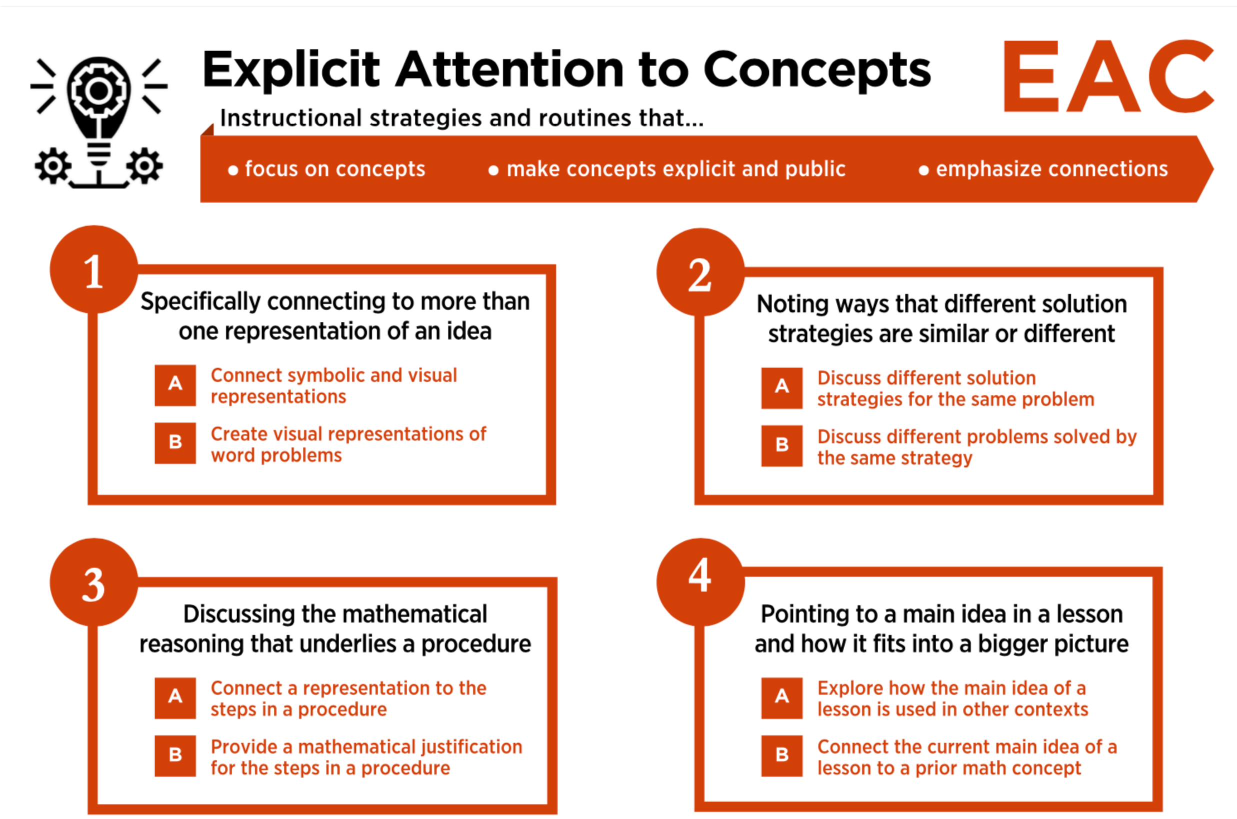

Figure 1: EAC/SOS Guide to Instructional Practices for Improving Math Achievement

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The EAC Guide is a research-to-practice document, intended to provide actionable information for teachers. However, there is an ongoing need to better understand what teachers who do EAC well actually do, such as to what extent they use the strategies as described in the framework, and if there are things teachers do which are not included in the framework. Therefore, this study seeks to answer the following research questions: (1) What strategies do teachers use when effectively enacting EAC in whole class discussions following individual or group work time? (2) How do teachers enact those strategies?

Methods

We used essential qualitative analysis (Lahman, 2022) to describe how teachers successfully implement EAC in middle school classrooms.

Participants and Data Sources

This study is set within a larger three-year study of instructional sequences of EAC and SOS involving 100 middle grades mathematics teachers. The eight teacher participants in this study are grade 6-8 mathematics teachers from seven schools within four school districts in Idaho. Of the four school districts, two are at 27% low-income families, one is at 28% low-income families, and one is at 48% low-income families. Of the seven schools, one is rural and the other six are non-rural. One school is a K-12 charter school, one is a K-6 school, three are middle schools (6-8), and two are junior high schools (7-9).

The 8 videos of classroom instruction selected for this study are a purposeful sample of exemplary implementation of EAC. Teachers participating in the research project were asked to submit three videos of their instruction. A total of 177 videos were of high enough visual and auditory quality to be analyzed for levels of implementation of EAC. The videos were scored by ROOT project researchers. Videos were parsed into five-minute long segments. Segments were evaluated with a rubric scale comprising three levels: implementing, partially implementing, and not implementing (Crawford et al., 2021). The scale was applied to each of the features of EAC, which resulted in an overall EAC score for that segment. Since we do not expect EAC to be prominent throughout a lesson, we then calculated a mean for each video's five highest scoring EAC segments (representing 25 minutes of instruction). We selected the first 8 distinct teachers when ordering the means from highest to lowest.

Data Analysis

At the first level of analysis, the first author watched all eight videos and selected all segments where the teacher brought the whole class back together following student work time on a math task because we anticipated seeing EAC most prevalent during these sections of the lesson (Stein et al., 2008; Stein et al., 2017). Then these selected segments were parsed into talk turns which were captured and timestamped. Then each talk turn was coded for who was talking: teacher, focus student (sharing their own work/reasoning), student in class (answering a question posed by the teacher), student table conversation, and whole class response).

Three project researchers participated in the second round of coding. We used the four strategies in the EAC Framework as a priori codes (Saldaña, 2021) to coded talk turns where EAC was present. The first author developed a codebook with the four strategies, the code name, examples, and coding decision rules. The a priori codes were: *Strategy Zero:* Clarifying the mathematical meaning within one representation, *Strategy 1:* Specifically connecting to more than one representation of an idea, *Strategy 2:* Noting ways that different solution strategies are similar or different, *Strategy 3:* Discussing the mathematical reasoning that underlies a procedure, and *Strategy 4:* Pointing to a main idea in a lesson and how it fits into a bigger

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picture. To calibrate coding, the three researchers watched and coded 1 video together using the codebook. During the coding of the first video, a new strategy emerged and we added it to the codebook. One important decision rule we added was: Student responses are only coded when they are sharing their own ideas, not just giving the answer the teachers is looking for.

Then each of the three researchers watched and coded a second video separately. Inter-rater agreement was determined by identifying the proportion of talk turns assigned to each strategy. We agreed that Strategy 1 was the predominant strategy. Rater 1 applied this strategy in 87% of coded talk turns, rater 2 applied this strategy in 85% of coded talk turns, and rater 3 applied this strategy in 78% of coded talk turns. We discussed and reconciled disagreements until 100% agreement was reached. The code book was refined after this calibration by adding new decision rules.

After this calibration meeting, the remaining six videos were randomly assigned to each of the researchers. When a researcher felt uncertain about coding any talk turns, the team watched the segments and discussed until consensus was reached. This occurred three times.

The results were synthesized across the eight participant videos. We merged the observations together into a single data set. This allowed for cross-tabulation of strategy use across teachers, allowing us to answer the question of what strategies were used; as well as percentage distributions of each teachers' relative use of the five EAC strategies (four a priori and one emergent), to answer the question of how they were used. To further answer the question of how teachers implement the strategies, we looked for patterns of how teacher and student talk turns were coded.

Findings

This study analyzed videos with high levels of the features of EAC. To answer the question of what strategies exemplary teachers use when enacting EAC in whole class discussions following individual or group work time, we present strategies used by the eight participants. To answer the question of how teachers enact those strategies we present the predominance of one strategy used by teachers more than others strategies within a lesson and vignettes as examples of how EAC was effectively implemented.

Strategies exemplary teachers use when enacting EAC

Emergent Strategy. We found that teachers utilized five strategies when enacting EAC. Our initial coding scheme and the framework only included four strategies. However, when the team met to code the first video, we identified an emergent strategy. In analyzing strategy use, we found segments in which teachers were focusing on concepts and representations but were not fully aligned to the strategies as described in the framework and codebook. We recognized these segments as examples of an emergent strategy. We named and defined this strategy as *Strategy Zero:* Clarifying the mathematical meaning within one representation. The teacher was clarifying key mathematical concepts and making the concepts explicit and public, but doing so within one representation, instead of making connections between two representations, as expected based on the EAC framework. We chose to call this Strategy Zero instead of strategy five, because we inferred Strategy Zero had a foundational aspect of clarifying within one representation before making mathematical meaning across more than one representation or solution strategy.

We added Strategy Zero to the codebook. As we coded the seven additional videos, we saw Strategy Zero present in other participant videos as well. In total, six of the eight participant videos included Strategy Zero. In two of these 6 videos, it was not only present, but it was the

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prominent strategy used during the lesson. The following vignette comes from the video where we first discovered Strategy Zero.

Vignette 1: Example of Strategy Zero. In this portion of the lesson, the teacher is using the example of stacking disposable Styrofoam cups with wide rims to help students learn about non-proportional relationships. She has physical cups in the classroom and a picture of stacked cups projected on the board.

> Penelope: When we think about doubling the height of the cup, what do we lose when we drop those cups into the stack? We lose the base of the cup, right? That part that we would hold on to and we are only left with the lip. So, some people still tried to double 15 [teacher gestures stacking cups with her hands] and they got 30, and then they did another stack of 15 and they got 45. They were getting closer to 50. But all they were doing was taking their stack of 15 and trying to put it like this [teacher picks up actual cups and demonstrates stacking the cups one on top of another without nesting them inside one another], right? Because there's 15, and then 15 again, and then another 15. But when we stack the cups, I spent a lot of time at the back row, because we started to realize that we needed to remove something. So, first we looked at taking our whole 50 cm [teacher gestures, indicating the height of a large stack with her hands] and then dividing it. And we divided it into these pieces that were 1.41 cm [teacher points to something on the board then indicates 1.41 cm with her thumb and index finger]. Divide, divide, divide.

Strategy Use Across Participants. We identifying the proportion of talk turns assigned by researcher to each strategy to answer what strategies teachers used. We found most whole class discussions focused on one predominant strategy during their video lesson. The most used strategy across all eight participants was Strategy 1: Specifically connecting to more than one representation of an idea. Four of the eight participants used Strategy 1 as their predominant strategy. Interestingly, the second most predominant strategy was our emergent strategy, Strategy Zero: Clarifying the mathematical meaning within one representation. Two participants used Strategy Zero as their predominant strategy. Strategy 2: Noting ways that different solution strategies are similar or different, was the predominant strategy for one participant and Strategy 3: Discussing the mathematical reasoning that underlies a procedure, was the predominant strategy for one participant. It is noteworthy that Strategy 4: Pointing to a main idea in a lesson and how it fits into a bigger picture, was the only strategy that was not a predominant strategy in any of the eight participants' video lessons.

How exemplary teachers enact EAC strategies

Strategy Use Within a Lesson. Since we found that most whole class discussions focused on one predominant strategy within the lesson video, we calculated the percent of talk turns that were coded for each strategy. Figure 2 shows strategy usage as a percentage of talk turns by teacher. Strategies are presented in numerical order from left to right and teachers are presented in alphabetical order of their pseudo names. Predominate strategies ranged from 46% to 97% of the total strategies present with seven of the eight participants using the predominant strategy between 70% to 97% of the time. Six out of the eight participants used their predominant strategy much more than any other strategy. Specifically, six of the participants had 63% or more difference between their predominant strategy and their secondary strategy.

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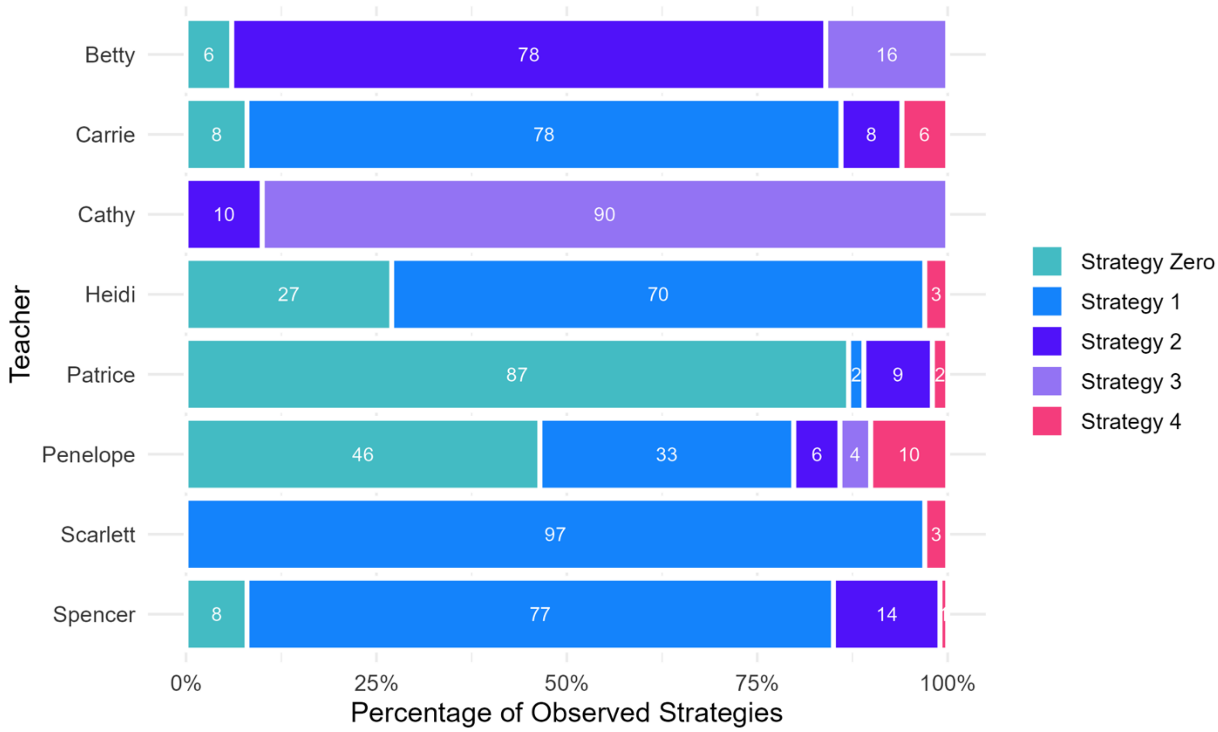

Figure 2: Percentage of Each Strategy by Teacher

We compared the number of strategies used by each participant. All participants used more than one strategy. One teacher used all five strategies, three teachers used four strategies, two teachers used three strategies, and two teachers used two strategies.

It is noteworthy that the pattern of use for Strategy 4 was distinct from that of other strategies. None of the eight videos included Strategy 4 as predominant strategy. Though, strategy 4 was identified in the majority of videos (six of eight), in every case this code was applied in no more than 10% of the talk turns. On average, in all eight videos, Strategy 4 was used 3% of the time.

Lesson Structure with EAC Present. When looking for patterns, we found a pattern in teacher – student interactions. We noticed that most videos had numerous uncoded student talk turns. We revisited the videos and identified these interactions as the Initiate-Response-Evaluation (IRE) structure where the teacher initiates a question with a right or wrong answer, a student responds, and the teacher evaluates their response (Mehan, 1979; Cazden, 1988).

Vignette 2: IRE Example of EAC. This vignette is from the video where we noticed the IRE structure showcases one example of an IRE exchange between the teacher and students. In this vignette, the teacher is asking students for the area of regions within a shape projected on the board. The teacher seems to be focused on getting answers using the area model to show the justification for the algorithm of multiplying decimals. All student names are pseudo names.

Cathy: Todd, what's the width of region C?
Student: Zero point four.
Cathy: What's the length?
Student: One.
Cathy: There you go.

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We analyzed the coding data from the other 7 videos and found that seven of the eight participants used an IRE format while enacting EAC in their classroom video lessons. Spencer was the only participant who did not utilize an IRE structure in their video lesson. As we looked for patterns, we noted that though the teacher's pattern of strategy use was similar, the talk turn structure was different. Specifically, the types of questions the teacher asked, the expectation of an explanation in student responses, and duration of student responses. Vignette 2 illustrates the pattern of student questioning we found in Spencer's video. All student names are pseudo names.

Vignette 3: Non-IRE Example of EAC. After launching a task with their students, Spencer has given them some time to work in groups on vertical whiteboards. While working only one student has a marker and only the other two students in the group can speak. In this vignette, students are back at their desks and Spencer is pulling them together for a whole class conversation about the work they have done so far. Spencer is trying to get students to use a double number line to show their proportional reasoning.

Spencer: So, this is what I'm seeing. I saw a number line that looked like this [teacher is writing on the board]. Give me a thumbs up when you've thought about it...K, my first question is, how would I label this? How would I label this and why? Ready? Thank you.

[Students begin talking with their groups].

Spencer: Camille, go for it. What were you two talking about?

Camille: Umm, well we were talking about it would be like zero to ten miles.

Spencer: So, it would be important to put down miles here. How come?

Camille: Because it is how many, like it's ten miles that he ran. So, it's important to write it.

Spencer: Thank you. Bradly?

Bradly: You could maybe do like, one, two, three, four, five, six, seven, eight, and nine.

Spencer: So, there's some miles that we can put in here, that you would agree with. Are you okay with labeling it miles?

Bradly: Yeah.

Spencer: Mary, how come?

Mary: So, I'm…the miles is like one part, and then the…so, the miles is like the 10 miles and then…cause you labeled it 10. And then the next number line is probably gonna be…units is the four hours.

This vignette is structured differently than an IRE format not only because student talk turns are longer in duration. More importantly, the teacher asks students to justify their answer and to justify another student's answer, but only after giving all students a chance to discuss ideas and justifications with their peers.

Discussion

Current research gives insight on what supports student learning (e.g., focus on conceptual understanding), however, we know less about the intricate details of how effectively implemented mathematics instruction is done. In order to better design learning environments that take student learning into account, we describe both what strategies teachers use when implementing EAC and how they implement these strategies.

Strategies exemplary teachers use when enacting EAC

All four strategies described in the EAC framework were seen in these videos. In addition, a fifth strategy was present. We identified and defined Strategy Zero as: Clarifying the

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mathematical meaning within one representation. We identified this as an EAC strategy because of the focus on concepts, making these concepts explicit and public, and the emphasis on connections. The teacher was connecting an abstract mathematical concept to a single visual representation of the concept. This is different from Strategy 1 because Strategy 1 is about connections between more than one representation of a mathematical concept. It is important to note that teachers were taking the time to allow students to make sense of mathematical concepts within one representation. We believe teachers were doing this either because they recognized they needed to take the time to make sense of a mathematical idea in and of itself or to address student misconceptions as they came up. We find this noteworthy because this is implicit, not explicit, in Hiebert and Grouws (2007). The synthesis explicitly focuses on connecting multiple representation. Thus, it was not included in the Champion et al. (2020) framework.

The idea of this kind of conceptual work for students is consistent with the theory of concreteness fading which suggests meaning needs to be developed within one representation before moving onto others (Fyfe & Nathan, 2019). We intentionally names Strategy Zero because we believe Strategy Zero may be a foundational strategy in that students would struggle to make connections between representations (Strategy 1) or between strategies (Strategy 2) without first understanding the mathematical meaning within one representation (Strategy Zero). This recognition made us wonder if there was a hierarchy among the strategies in the EAC framework corresponding to a feature theory of concreteness fading which hypothesizes that transitions to symbolic procedural mathematics happen gradually. We are wondering if there is a progression from concrete to the abstract. When teachers feel the need to utilize Strategy Zero, should it always precede Strategy 1? Likewise, should Strategy 1 always precede Strategy 2 and so on? In order to add additional detail and clarity about these strategies for teachers in their classrooms, this possible hierarchy is worth exploring further.

How exemplary teachers enact EAC strategies

We found that teachers choose one predominant strategy to implement within a lesson, always with other strategies present, but, often with the other strategies much less present. This suggests that teachers find it beneficial to spend time within one strategy, to do it well, and not plan multiple strategies within a short period of time.

We found that teachers who used Strategy 4, only did so briefly. This strategy was used by six of the eight participants, but was never the predominant strategy. This suggests that teachers find Strategy 4 important enough to utilize, but that little time needs to be spent on Strategy 4 in order for Strategy 4 to be effective. Hiebert & Grouws (2007) point to the importance of reminding students of the main idea of the lesson and how it fits into the bigger picture and we found most of our teachers enacted this for at least a portion of their lesson.

We were surprised to find that seven of the eight participants used an IRE format while implementing EAC. Because these videos were selected as exemplar of EAC, we expected to see discussions that aligned more with the 5 Practices (Smith & Stein, 2011) which involve more student led discussions. However, this confirms previous claims that IRE is the default structure for classroom discourse (Cazden, 1988). We wonder if this is due to teacher training in IRE for making ideas explicit and public for students, and if this is the strategy teachers are familiar with and therefore use. The non-IRE strategy is of great interest to us. In this example of EAC without an IRE format, students may have had more voice and authority in the classroom (Cazden, 1988). It is also noteworthy that the teacher was able to implement EAC within the same timeframe as other teachers who were using an IRE format. Additional examples of EAC without an IRE format is worth exploring further.

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