The Impact of Metacognitive Instruction on Students' Conceptions of Learning and their Self-monitoring Behaviors

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Introduction

One's beliefs about learning, accurate or not, direct what one does to learn (Barzilai and Zohar 2016; Muis 2007). Humans are also prone to trust and repeat what is familiar and comfortable, whether it is the most effective and efficient or not. In a learning context, mental models of learning are durable, built up over years of prior experience, and are resistant to change (Ozubko and Fugelsang 2010). In this study we implemented metacognitive instruction within a first-year engineering course at a small engineering program within a large public university and sought to understand if and how students' conceptions of learning change with metacognitive instruction. We further sought to understand if and how metacognitive instruction affects the alignment of students' self-monitoring behaviors and their conceptions of learning.

Ample literature shows that misconceptions about concepts are robust and difficult to change (Taylor & Kowalski, 2014). Misconceptions about learning are similarly robust and difficult to change (Barzilai & Zohar, 2016; Muis, 2007). We can think of students' conceptions and approaches to learning as mental models or scripts. Students' scripts for learning and self-regulatory processes are ingrained and durable, reinforced by a multitude of prior learning experiences, social dimensions, and cognitive variables (Matthews, et al., 2005; Zimmerman, 2005; Jonassen, 2011, 2014; Lee, et al., 2013). For example, students have been consistently rewarded with good grades using primarily rehearsal strategies, such as, pattern matching and memorization (Birenbaum, 1997; Scouller, 1998; Segers, et al., 2006). This reinforces scripts where learning is thought to mean memorization and replicating processes. In fact, students primarily rely on rehearsal strategies, which limits them to surface learning and fragile memories (Atkinson & Schiffrin 1971; Jarrold, et al. 2011).

Students carry their scripts for learning forward to subsequent learning contexts, even when the expectations have changed. College presents new expectations for lasting and transferable learning and critical thinking (Eccles, 2004). In engineering education we increasingly expect students to retain knowledge from pre-requisite courses. Further, we engage students in ill-structured problems, often oriented around design or analysis, where they have to sort through prior knowledge to identify what applies and recall how to apply it. Students' rehearsal habits are insufficient for developing this type of contextualized, contingent, and interconnected knowledge structure.

Changing students' scripts for learning is hard and takes time. Conceptual change literature identifies four conditions required for such changes to occur: 1) students must experience dissatisfaction with their current beliefs and behaviors (they are insufficient); 2) the new beliefs and behaviors must make sense (they are intelligible); 3) students must be able to apply the new beliefs and behaviors (they are plausible); and 4) the new beliefs and behaviors must be fruitful and endure challenges (Bendixen 2002).

Previous studies have shown that metacognitive instruction positively impacts student learning, but most of these studies are conducted with children in K-12 settings (Dignath & Buttner, 2008; Schraw & Gutierres, 2014). Here we extend metacognitive instruction to engineering education at the college level. Our metacognitive instruction is aligned with the necessary elements for conceptual change. Within our study we targeted students in transition, because during transitions in learning contexts students are wrestling with adjustments and are already needing to make changes (Eccles, 2004). We used explicit instruction in the form of metacognitive modules to build students understanding and regulation of their thinking and learning processes. These modules also provided students opportunities to practice new strategies for learning and self-monitoring, receive feedback, and reflect on outcomes. We focused on student self-monitoring because it is a key element of metacognition as it is instrumental in directing learning behaviors (Zimmerman 2005; Winne, 2005). The accuracy of self-monitoring is particularly important for successful learning (Schraw & Gutierres, 2014).

Methods

Our overall study is a quasi-experimental study with a pre/posttest design with an intervention (Krathwohl, 2009). We did not have a control group. All students participated in the intervention and they were invited to self-select into the research.

Site and Intervention Description

Our research site was a small engineering program within a large public university. We focused on a one-credit first year course taken by all students, including transfer students. The course objectives include gaining familiarity with engineering disciplines and engineering careers, strategies for success in the engineering degree program, exposure to resources available at the institution, and engineering ethics. The course meets in a large group format once per week, then in smaller groups (approximately 30 students) once per week. Both the large group and small group course meetings are led by faculty.

The metacognition intervention included a series of modules that started in about week 6 (of 15) of the course. Greater detail about the purpose and design of the modules has been reported elsewhere (Cunningham, et al., 2015; Cunningham, et al., 2016; Cunningham, et al., 2017; Williams, et al., 2016), though the modules generally include a video about an element of metacognition and activities to be done inside and outside of class. The pre- and post-tests were completed during the small group meetings just before the modules began (week 5) and just after the last module (week 15). In this application, the modules were generally presented as follows:

- The video was shown and a set of reflection questions were assigned and collected during the large group meetings
- For half of the modules (Overview, Knowledge, and Planning), additional reflection questions were assigned and collected during small group meetings with attempts at discussion and making connections to the course text, *Studying Engineering* (Landis, 20??). For these modules, students were also asked to answer a reflection question as a post class journaling assignment.

Grading for the metacognition-related assignments was primarily based on completion and effort and counted towards the class participation portion of the grade.

Sample Population

In total, 76 participants responded to the pre-test survey (pre-test) and 74 participants responded to the post-test survey (post-test) with a total of 70 participants responding to both surveys. We have included those 70 responses in our analysis. The majority of students identified as first year although the sample included second, third and fourth year students as well.

Data Collection

Our survey instrument included both open- and closed-ended questions. Some of the questions were original (i.e., designed by our research team) and others were modifications of existing instruments. The first part of the survey assessed students' perceptions of their own engagement in learning and metacognitive activities. The second part of the survey was designed to examine students' motivation to engage in learning about metacognition and drew on existing instruments designed with Eccles' Expectancy Value Theory (EVT) (Wigfield & Eccles, 2000). The third part of the survey gathered demographic information including sex, race/ethnicity, and academic status (e.g., first year, graduate student, etc.).

For this current analysis, we focused on a subset of the questions related to metacognition as described in the analysis section. We created these questions specifically for our intervention modules though we drew on existing literature. Research has shown that metacognition can be difficult measure (Van Hout-Wolters 2000; Veenman, et al. 2006; Winne and Perry 2005) and our goal was to provide teachers with a simple and practical tool to understand where students are with regard to metacognitive practices before and after the intervention. Our questions draw on data collected across the larger research project regarding how students say they learn and the kinds of questions existing instruments ask about metacognition (Pintrich, et al., 1991, 1993). Our format of using open-and closed ended questions together is similar to the approach described by Lee, et al. where the closed-ended questions provide context for and ground the open-ended questions (Lee & Lutz, 2016).

Analysis

Our analysis approach included open-coding of responses to open-ended questions and quantizing these responses as well as descriptive and comparative statistical analysis from quantized and closed-ended responses. Open-coding means allowing the code to emerge from the data (Patton, 2002). Therefore, the codes were emergent from the total pool of survey responses.

Open-coding and Quantizing Open-Ended responses

Both the pre-tests and post-tests included an open-ended question asking: What does it mean to learn something? Responses were open-coded and then grouped into the categories in Table 1. We counted the number of instances of each of these in the responses to the pre- and post-test. Our approach is consistent with what Tashakori and Tedlie (Tashakkori & Teddlie, 1998) call “quantizing” qualitative results and it is a technique that is useful with open-ended responses (Borrego, Douglas, & Amelink, 2009).

Table 1: Open-Coded Conceptions of Learning

Code	**Example**
To obtain information	Participants cited simply, “to acquire new knowledge” especially as it applied to the new context such as, “to gain new knowledge about a topic/concept you knew little about”.
To understand	The “to understand” label was the most vague. Participant responses include, “to understand information” or, “to fully comprehend the new knowledge”.
To know a process/ application	Participants noted, “to become aware of a process” and, “to be able to apply the process when I need it”
To memorize and recall	This label is best described by participant responses such as, “to familiarize yourself with the concept to recall and use it later” and “to retain new information”.
Be able to explain it to someone else	Participants cited “to be able to teach what you know” and “to share your skills with your peers”.
To grow holistically as a person	This response only appeared in the posttest responses. Participants cited learning meant that “you are growing as a person”.

We similarly analyzed the responses to the open-ended question on what prompts students to think about their learning. Codes and definitions are show in Table 2. We counted the number of instances of each of these in the responses to the pre- and post-test.

Table 2: Open-Coded Prompts to Think About Learning

Code	Example
Unexpected grade	"When I do very poorly on homeworks" or "When I received a good grade" "If my grades are dropping for some reason"
Want to learn new study strategies	"When my strategies don't work, I know I have to seek new ones", "To see if I could improve by using something else"
Not understanding course content	"When I don't understand a topic", "When I get confused and don't understand the material"
Planning for difficult parts of the semester/course	"Having a lot of responsibilities to manage", "Before a test or homework"

We quantitatively analyzed responses to a question that asked about how frequently students think about their learning. This data was first converted to ordinal values with 0 being "Never" and 5 being "Daily." Because our data is not continuous or normally distributed, and it is ordinal, we used a non-parametric test, specifically the Wilcoxon Signed Rank test using SPSS. We had a total of 66 paired responses for this analysis (pretest and posttest).

Results

Our results are organized to first examine students' conceptions of learning where we note changes from pre-test to post-test based on open-coding. We then examined how often and what students do to monitor their own learning. Finally, we examined why students do what they do by examining responses to an open-ended prompt.

Conceptions of Learning

In analyzing our pre- and post-test data, we found differences. Table 3 shows the number of times each category appeared. Figure 1 shows a comparison of the quantized responses to the question *what does it mean to learn something?* We found that in the pre-test, participants cited that learning meant "to obtain information" most frequently. This response dropped in frequency during the post-test. The most common response in the posttest is "to understand". The response "to know a process/application" increased in frequency from the pre-test to post-test.

Table 3: Pre and Post responses to what it means to learn

Pre	Post
To obtain information (30) To understand (24) To know a process/application (10) To memorize and recall (8) Be able to explain to someone else (4)	To obtain information (17) To understand (27) To know a process/application (18) To memorize and recall (7) Be able to explain to someone else (2) To grow holistically as a person (3)

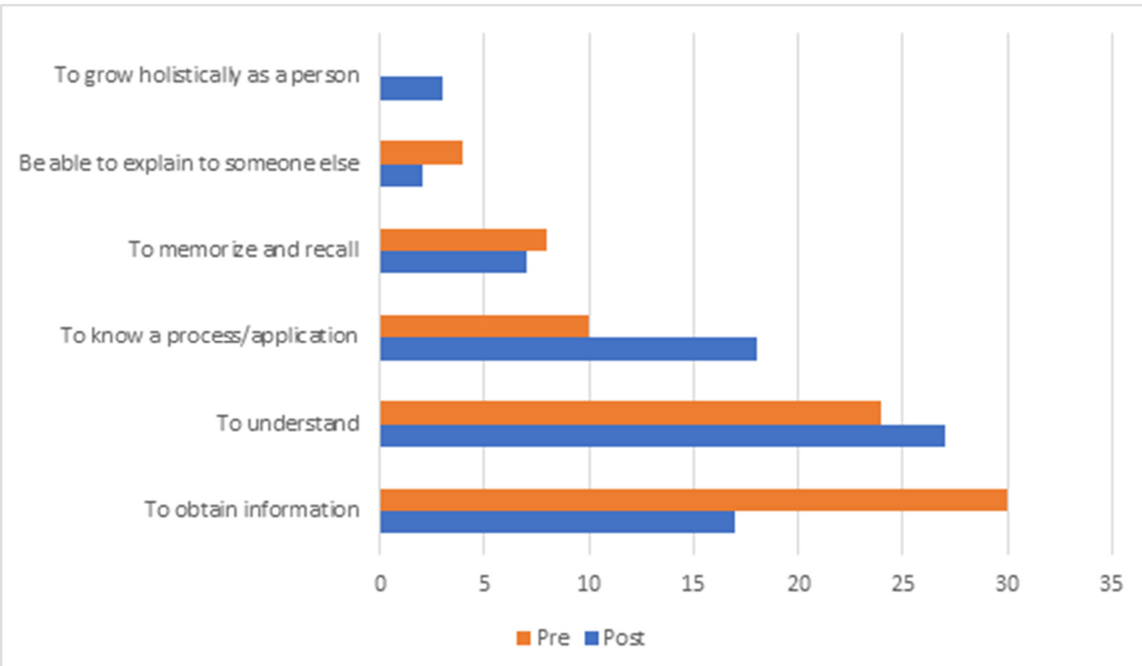

Figure 1: Comparing number of citations for the categories of responses defining learning

Monitoring for Understanding

Analyzing the open-ended question paints a picture of what students think it means to learn something. We then wanted to understand how often they thing about learning, what they do to monitor their learning, and what prompts them to think about their learning.

Figure 2 shows responses to the question, *How often do you think about your approaches to learning?* Response choices ranged from Never to Daily. Strikingly based on the frequency chart, it appears that post responses decreased in frequency on average with once per week being the most common response. Unfortunately, the statistical analysis did not reveal a significant change. Rather we see that:

- Number of responses in which the post-test score is higher than pre-test score: 24
- Number of responses in which the post-test score is lower than pre-test score: 22
- Number of responses in which the post-test score is same as pre-test score: 20

The Wilcoxon Signed-Ranks test indicated that the pre-test scores were not significantly different from the post-test scores ($Z = -0.411$, $p = 0.05$). Indeed, median scores were 3.00 for both pre and post.

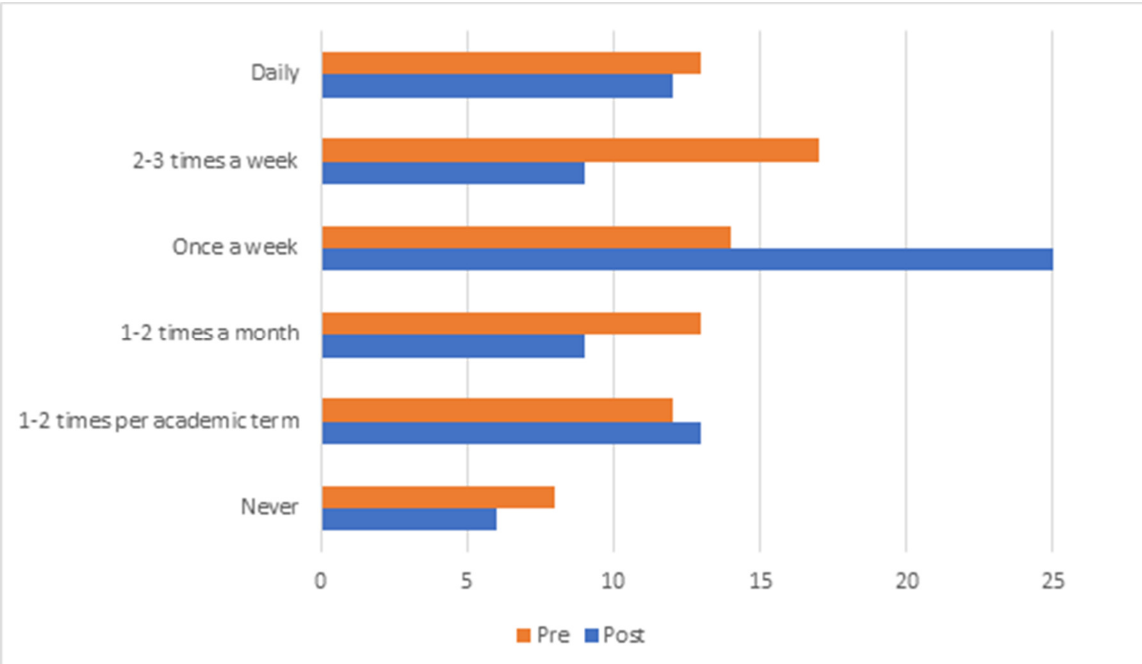

Figure 2: Pre and Post comparison of frequency of engaging in monitoring

Figure 3 shows a comparison in response to the prompt *Proportionally, what percentage of your time do you spend doing the following things in your engineering class?* This was a closed-ended question followed by a list of activities such as massed practice, reading reviewing notes, etc.). In the pre-test response, the most common answers were (in descending order) reread/review notes, review homework, and massed practice. Timing one-self on an old exam without supports was the least common answer both pre- and post-test. The three highest activities remained high (pre to post). Comparing pre-post responses did not reveal any statistically significant differences.

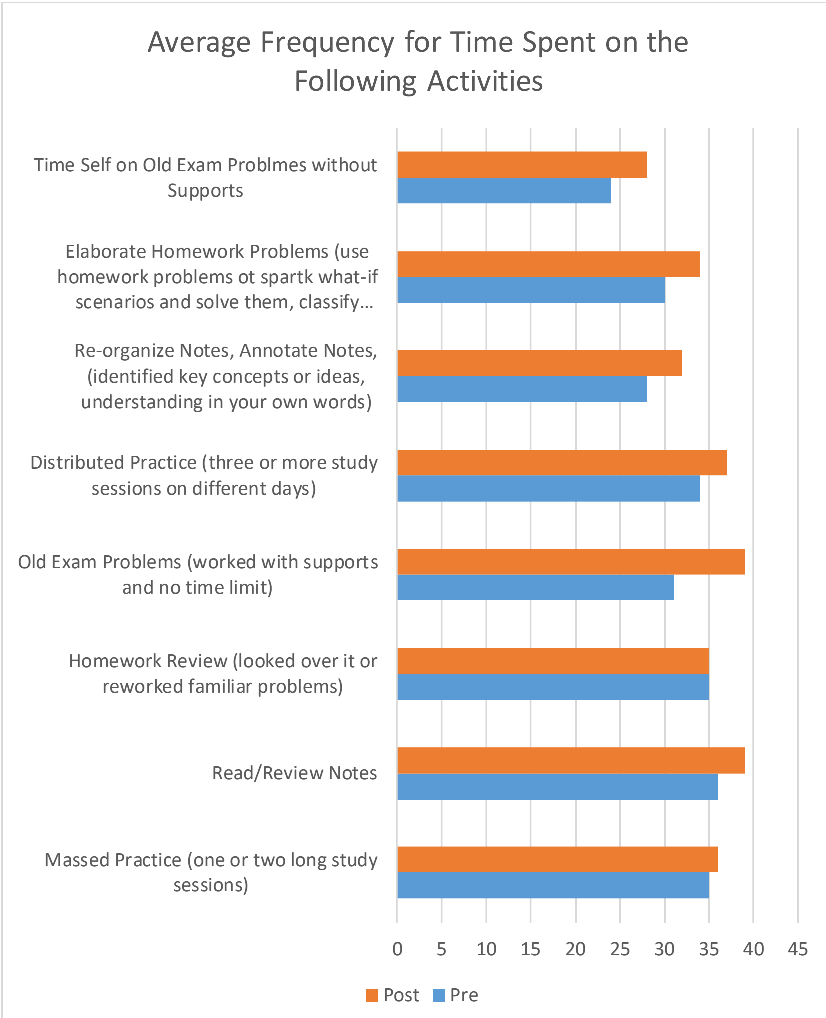

Figure 3: Pre and Post comparison of how time is spent (by percentage not total hours)

To understand why they are doing what they do we examined responses to the open-ended prompt, *What prompts you to think about your learning?* Although we anticipated a change based on responses to other questions, we did not see one. Table 4 shows the categories identified through open-coding and Figure 4 shows a comparison of the number of times each was cited pre and post.

Table 4: Pre and Post responses to prompts to monitor learning

Pre	**Post**
Unexpected grade (27) Want to learn new study strategies (17) Not understanding course content (17) Planning for difficult parts of the semester/course (6)	Unexpected grade (23) Want to learn new study strategies (20) Not understanding course content (14) Planning for difficult parts of the semester/course (8)

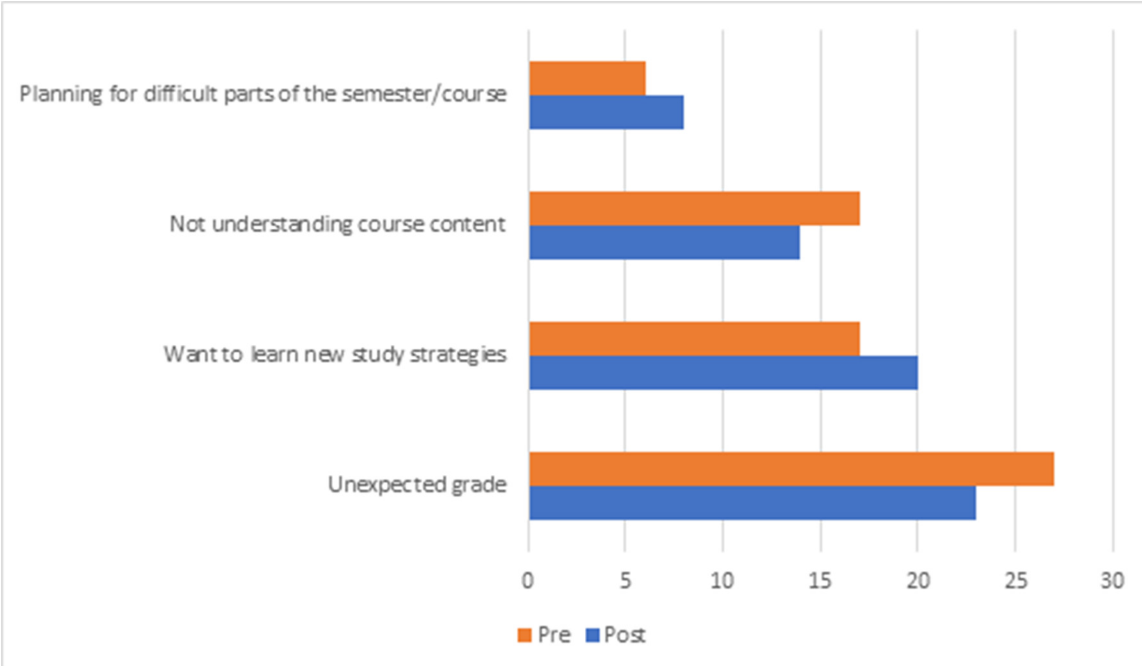

Figure 4: Comparing number of citations for the categories of responses for what prompts monitoring

Limitations

Our study has several limitations. First, our intervention is relatively short-term (i.e., lasted one semester) and research shows that it can take time for people to change habits and practices to which they hold fast and believe are robust. We also recognize that our pre-post data comparisons may not be equivalent because the changes in post-intervention data could reflect students having developed language to talk about what they are doing and better understanding of learning processes generally. This is similar to arguments made for not giving students concept inventories as pre-tests because they lack sufficient language to complete the assessment (Steif & Hansen, 2007).

Discussion

Despite a lack of statistical significance, we believe our findings are meaningful and we offer an interpretation. Our findings also have implications for instructors, students and researchers.

Interpretation of Results

When we look at student's conceptions of learning, we see a marked shift from obtaining information to understanding information. The idea of obtaining knowledge (prevalent in the pre-test) goes along with the idea of didactic learning where the instructor pours knowledge into the minds of students (Smith, et al., 2005). In the post-test, we see a shift from obtaining knowledge to understanding. We recognize that understanding is a vague term, but we believe it represents a shift towards taking ownership of the learning such that the knowledge is not just obtained from the instructor but is processed in some way by the student to yield understanding.

When we consider monitoring of learning, we noted that the frequency of monitoring learning seemed to decrease from pre- to post-test (though it was not statistically significant). We hypothesized that this is because students have a better understanding of what it means to learn and are therefore making a more accurate assessment, which yields the changes in frequencies reported. At the same time, as we note in the limitations it can take time for learning habits to change. Therefore, the frequencies reported posttest might also be unstable accounts.

We had hoped we would see a marked difference in the strategies students were using to monitor their learning particularly as we saw the shift from obtaining information to understanding information. However, we saw no differences. Again, we believe this is associated with a need for more time and practice to see changes in habits.

Implications for Instructors and Students

Our results have meaningful implications for instructors who intentionally work towards helping students understand their own learning. Importantly, do not get discouraged. Use multiple measures as we did to see nuances in the results. Because metacognition is difficult to measure and habits are hard to change, helping students learn to be more metacognitive is a process. We believe that our data confirm this and that instructors need to understand this phenomenon and work with it and not against it. First steps include developing a common language between instructors and students.

Similar to our implications for instructors, students need to recognize that just as learning content is a developmental process so too is learning to engage in supportive metacognitive practices. Thus, learning to learn better requires patience and targeted effort.

Implications for Research

As literature has already shown, measuring metacognition is difficult (Winne & Perry, 2005). In essence, by asking about metacognition, the researcher is asking the participant to engage in metacognition which undoubtedly impacts the response. We believe the pre/posttest design around an intervention can be particularly challenging because the intervention could change the meaning of the questions for the participants as noted in the limitations. Therefore, there is a need to continue to develop useful and meaningful instruments to measure metacognition and to continue to interpret findings with the limitations of the instruments in mind. We believe that it is important to ask multiple questions from multiple perspectives to be able to assemble a comprehensive understanding of what is happening for learners.

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