Pedagogical sensemaking or “doing school”: In well-designed workshop sessions, facilitation makes the difference

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(Received 22 February 2017; published 24 October 2017)

Although physics education researchers often use workshops to promote instructional change in higher education, little research has been done to investigate workshop design. Initial evidence suggests that many workshop sessions focus primarily on raising faculty’s awareness of research-based instructional strategies, a fairly straightforward goal that has been largely met. However, increasing faculty’s awareness of existing strategies alone has somewhat limited benefits. We argue that workshop leaders should also aim to cultivate faculty’s ability and motivation to engage in pedagogical sensemaking, i.e., the pursuit of robust pedagogical logic based on observations and interpretations of classroom events. This goal is likely more challenging to achieve, and thus presents a greater need for research. In this paper, we pursue *in situ*, qualitative analysis of two parallel workshop sessions that seem to have the potential to support ambitious outcomes. We demonstrate how faculty may engage in aspects of pedagogical sensemaking, such as using observations of student behavior to support their arguments. We also show how faculty may instead seem to engage in interactions reminiscent of students “doing school,” such as evaluating instruction based on “correctness” alone. We also show how differences in workshop facilitation seemed to contribute to faculty engaging in pedagogical sensemaking in one session only. These differences include (i) strictly enforcing session rules versus gently navigating faculty’s incoming expectations, (ii) highlighting the workshop leaders’ expertise versus working to minimize power differentials, and (iii) emphasizing the benefits of adoption of a prescribed strategy versus encouraging faculty to reason about possible adaptations. We consider the implications of this analysis for future research and workshop design.

DOI: 10.1103/PhysRevPhysEducRes.13.020123

I. INTRODUCTION

It is widely recognized that the incorporation of research-based instructional strategies (RBIS) and principles into undergraduate STEM classes can improve student learning and retention [1,2]. Similarly, growing evidence suggests that the use of RBIS can increase opportunities for all people to participate and thrive in STEM [3–5], although more work is needed to understand what strategies are most likely to increase equity in the classroom [6–11]. Faculty are centrally positioned within this landscape: they can shape their students’ experiences, they can play a significant role in advocating for change within their institutions [12–14], and they have access to valuable knowledge about their local contexts. This creates a strong case for involving faculty as partners in instructional change—both in teaching them what we know now and in working with them as

we continue to explore ways to create better classroom environments.

Within physics and other STEM disciplines, professional development (PD) workshops like the Physics and Astronomy New Faculty Workshop (NFW) have had a significant positive impact in promoting the use of research-based teaching [15–18]. In particular, the NFW has reached a large percentage of physics faculty: 25%–50% of all tenure-track hires since 1996 have attended. A majority of physics faculty are now aware of (88%) and have tried implementing (72%) RBIS in their classrooms, and attending the NFW is the strongest predictor of both of these faculty characteristics [16].

Despite these successes, the widespread, sustained use of research-based instruction in undergraduate STEM classrooms has not yet been realized [16,19–22]. In physics, one-third of faculty who try out RBIS discontinue their use after a single semester [16], and many perceive barriers to using these strategies [23]. Moreover, some faculty who use RBIS modify them in ways that seem likely to decrease their potential impact [24]. These limitations are perhaps not surprising: most faculty primarily learned to teach by watching their own instructors, and therefore are more comfortable using “traditional” instructional methods like

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lecture [25]. These remaining challenges suggest that faculty have not received sufficient support and training to successfully incorporate RBIS into their instruction.

One way to improve this situation is to critically examine the design of PD workshops. In particular, we argue that workshops should both (i) raise faculty's awareness of existing RBIS and (ii) actively encourage faculty to engage in sustained, inquisitive, and evidence-driven instructional experimentation both alone and with their peers. Workshops that follow these guidelines could help faculty to iteratively refine their instruction over time while also drawing on potentially useful education research findings. We also argue that many workshops could be substantially improved in this way. Specifically, our recent research reveals that many NFW sessions have been primarily authoritative, lecture-based, and/or lacking in opportunities for faculty to reason about instruction [26]. While our observations likely reflect an intentional decision by NFW leaders to focus on the first goal that we highlight [18], we suspect it also reflects of a lack of scholarly investigation into alternative workshop session designs that target more ambitious, complementary goals. We aim to address this limitation here.

The remainder of the paper is structured as follows. We describe and justify the theoretical commitments that underlie our work in Sec. II. We synthesize literature relevant for our analytical approach in Sec. III, including Sandoval's conjecture mapping framework [27] and characterizations of two kinds of learner interactions—"doing school" and sensemaking—that we argue can apply to faculty interactions during workshops. We describe our methodology for capturing, selecting, and analyzing two NFW sessions for the qualitative case study that comprises the body of this paper in Sec. IV. We present our analysis in Sec. V. We then discuss specific implications for workshop design and facilitation in Sec. VI, and consider broader implications for workshop leaders and researchers in Sec. VII.

II. THEORETICAL APPROACH

Our theoretical approach combines the varied perspectives of Hammer *et al.* [28], Vygotsky [29], and Cohen *et al.* [30], as well as other scholars who hold similar views. As we explain below, Hammer *et al.*'s "resources" framework [28] enables us to talk about faculty's thinking in nuanced ways that align with our commitment to treating them as valued partners in instructional change, while Vygotsky's view [29] on the nature of learning and Cohen *et al.*'s broader definition [30] of instructor resources enable us to consider a full range of factors that importantly shape faculty's thinking and learning.

A. Cognitive resources

Hammer *et al.* [28] describe learners' knowledge as being divided into potentially productive, yet potentially uncoordinated pieces or resources. They suggest that

cognitive resources (i.e., learners' ideas) will be cued up or activated in ways that match the learner's sense of what is happening at that moment, where the learner's answer to "what is it that's going on here?" is called *framing* [[28], p. 9] [31,32]. Hammer *et al.* [28] conceptualize learning as a process of activating resources in different ways, gradually reorganizing, coordinating, and refining these sets of ideas within a particular context. As learning occurs, the reorganization of learners' ideas develops stability such that a particular context or framing ultimately activates more appropriate resources for the situation at hand.

This complex view of knowledge can help us to identify building blocks in faculty's current thinking, even when faculty primarily value "traditional" teaching methods. It also diverges from much of the prior research on faculty's knowledge. Many researchers have assumed *a priori* that faculty have coherent and self-consistent conceptions of teaching and learning [33–36]. In this view, instructors whose ideas are less aligned with education research findings might conceptualize teaching as transmitting information and learning as accumulating information [34]. Focusing only on these apparent deficiencies could discourage education researchers from thinking of faculty as capable agents of instructional change. Conversely, identifying faculty's resources instead might help researchers to form genuine intellectual partnerships with faculty.

It is also analytically useful to treat faculty's knowledge as a collection of fragmented and context-dependent resources. When interpreting faculty's talk, a resource-oriented stance draws attention to the significance of the context faculty perceive themselves to be in. Consistent with this idea, researchers have found empirical evidence that instructors indeed draw on different sources of knowledge at different times and/or in different settings [37–39]. For our work, this suggests that faculty's perceptions about the nature of a workshop session could be based on their incoming expectations about the workshop, the breadth of their prior experiences, and/or the framing communicated by the workshop leader and other participants in the moment. Thus, which kinds of ideas are activated for faculty at a given time, as well as how various instructional choices might help faculty to think of different ideas, becomes a central question for research about faculty learning.

B. Interactions and distributed resources

Despite the value in exploring faculty's cognitive resources and the framing of learning environments, this theoretical view alone would result in an incomplete picture of how to support faculty's learning about teaching. Specifically, we might overlook some key factors likely to influence the form of faculty's future instruction if we restrict our view of learning to a process that occurs in an individual's head. Faculty's ways of reasoning in workshop sessions likely depend on more than their own prior ideas and the framing they adopt. The materials or tasks that

faculty are asked to engage with, how faculty interact with each other, and what workshops leaders say or do to facilitate these interactions with people and materials could also matter. Moreover, other researchers have suggested that the potential for instructors to move ideas and practices from workshops to classrooms is likely contingent on the extent to which these contexts appear to be similar [40]. While a resources framework can begin to illuminate these aspects of faculty learning, it does not foreground them.

With this in mind, we broaden our view to take up theoretical elements from Vygotsky and the many scholars who have interpreted and expanded on his work [29, 41–45]. From a Vygotskian perspective, interactions with other people and physical tools can serve as mediators of thought, and should be considered an integral and inseparable part of thinking and learning [29,44,45]. While individuals' own thoughts play a role in their learning, their interactions are the developmental precursors of what they can later internalize. Thus, from this perspective, analyzing interactions with other people and tools becomes a valuable, if not critical, way to understand learning.

In our aim to encompass these two separate theoretical traditions, we take up a second, common definition of resources from teacher education research and thus expand our use of the term to be more aligned with the Vygotskian tradition. Cohen *et al.* [30] independently put forward a wide range of teacher resources which include conventional resources such as curricular materials, classroom space, and class size; personal resources such as faculty's knowledge and interests, as well as students' knowledge and interests; and environmental or social resources such as local norms and social support from peers or administrators. Consistent with our argument above, these resources could play a significant role in launching or sustaining various ways of faculty thinking. For instance, students' expectations and questions, social pressures from colleagues, and inherited curricular materials could either promote faculty's use of research-based instruction or reinforce more traditional instruction [40].

This broadened definition helps us to more clearly articulate theoretically driven implications for workshop design: the potential importance of this array of resources to faculty's learning suggests that during well-designed, ambitious PD workshops, faculty will be able to draw on a wide range of resources that can cut across workshop and

local contexts and lend stability to their use of research-based teaching strategies.

III. ANALYTICAL APPROACH

Our theoretical perspective suggests that the nature of faculty's interactions are critical to their learning. Faculty's prior ideas and experiences clearly influence their interactions at workshops and elsewhere. However, PD leaders can also importantly shape workshop interactions through a variety of mechanisms. In keeping with this perspective, we use analytical tools that allow us to draw attention to all of these aspects of faculty learning. In this section, we describe our analytical framework and two likely characterizations of faculty's interactions during workshop sessions.

A. Conjecture mapping

We adopt Sandoval's analytical framework [27] of *conjecture mapping* to delineate different elements of PD design and the relationships between them. As shown in Fig. 1, Sandoval [27] defines three distinct components of educational design: embodiment, mediating processes, and outcomes. In the context of our study, *embodiment* describes the ways that PD workshops are structured. This would include the tasks that faculty are asked to engage with, how faculty's interactions are structured, the nature of the workshop leader's facilitation, and characteristics of the faculty participants themselves. *Mediating processes* describe what faculty think, say, and do as they interact with other people and materials during workshops. Finally, *outcomes* describe what changes for faculty as a result of their participation.

Beyond simply defining these components, Sandoval [27] argues that it is critical to make conjectures about the ways that the embodiment of a particular design is linked to particular mediating processes, which he calls *design conjectures*, and the ways that these mediating processes are linked to particular outcomes, which he calls *theoretical conjectures*. These conjecture maps allow researchers to articulate and iteratively test hypotheses about how learning is supported in a given context. Sandoval's framework [27] brings learners' interactions to the foreground, which closely aligns with our theoretical commitments and counteracts a common (sometimes practically motivated) tendency to attempt to directly link embodiment to outcomes.

FIG. 1. A visual representation of conjecture mapping for workshop design. Adapted from Sandoval [27], Fig. 1.

While it is relatively rare for teacher PD research to follow a similar analytical logic to what Sandoval [27] proposes, some examples, largely in K–12 contexts, do exist [40,46–55]. For example, Horn and Little [46] identify sharp differences in the productivity of two teacher workgroups’ conversational routines (what Sandoval [27] would call mediating processes), and hypothesize that these differences are linked to three key structural factors present in one group but not the other. Using Sandoval’s framework [27], we can summarize Horn and Little’s findings [46] as follows: if teachers share a principled pedagogical toolkit, have concrete and coherent curricular materials on hand, and work with leaders who enforce group norms, then productive group routines will emerge. Conversely, Horn and Little [46] hypothesize that if these embodiment structures are absent, productive group routines will not arise.

In this paper, we use a similar analytical approach to Horn and Little [46]. Specifically, we will focus on modeling faculty’s interactions and considering why these interactions emerged, i.e., on developing a detailed and robust set of design conjectures, also using contrasting cases. In this way, we lay groundwork for other researchers or workshop leaders to empirically investigate what outcomes emerge from these interactions, but do not pursue this work ourselves. Instead, we focus on developing plausible links between differences in session embodiment, namely, the workshop learners’ facilitation, and the mediating processes that emerge. This analysis can enable us to better understand what supports productive faculty interactions during workshop sessions, which we see as critical for promoting ambitious workshop goals.

B. “Doing school” versus pedagogical sensemaking

In this section, we consider two characterizations of the mediating processes we might expect to see during workshops (where one seems more desirable than the other), as well as the facilitation moves and other structural features that might lead to these two kinds of interactions.

1. Doing school

While we hope that faculty will engage in workshop sessions in productive ways, we suspect that workshops have the potential to cue up faculty’s ideas about how to act based on what they experienced as students [56]. These learned behaviors may be counterproductive. Students often engage in what researchers call doing school [57,58] in order to advance through academia: they adapt their behaviors to match anticipated academic rewards, even if this suppresses meaningful learning [57–62]. Because many current faculty members were likely among the “best and brightest” students, it is likely that they engaged in such behaviors at various points.

Within science classrooms specifically, students may do school by enacting assigned procedures or steps for a scientific task [58]. Students tend to recognize what

procedures they are “supposed” to follow to gain the instructor’s approval and a passing grade. These well-behaved students do not pursue more rigorous scientific explanations when the task itself is limited or ask questions that might naturally follow from their experimental findings. Students likely do not think about the purpose of the assigned steps relative to the substance of the task, and they are not encouraged to do so.

In interactions between students and instructors, frequent use of the initiate-respond-evaluate (I-R-E) pattern of discourse can support school-like norms [60]. Instructors may use I-R-E with the aim of “get[ting] students to know the scientifically accepted answers the scientists have developed to describe the natural world” but at the expense of “build[ing] sensible and plausible models of the natural world that are intelligible to the students themselves” [59]. Researchers have described this distinction as answer making versus sensemaking, where answer making is part of what comprises doing school.

While faculty doing school in the context of professional development activities will not be identical to these characterizations of science classrooms, we suspect that highly similar norms could develop during workshop sessions, and be cued up in similar ways. In our prior work, we observed faculty engaging in traditional school-like behaviors when completing a task designed for physics students during the NFW, such as literally trying to act like “good” students as if to appease the workshop leader [56]. These interactions seemed to be at least partly cued up by the workshop leader’s actions and talk. Here, we seek to uncover additional examples of what faculty doing school might involve and why it might emerge.

2. Pedagogical sensemaking

As a promising alternative to doing school, workshop sessions could instead lead to faculty engaging in what we call *pedagogical sensemaking*. We define pedagogical sensemaking to be the pursuit of robust pedagogical logic based on observations and interpretations of classroom events, particularly explanations of how instructional moves seem to influence students’ engagement and learning [63]. We argue that instructors must routinely reason in these grounded ways in order to generate and iteratively refine their specific instructional plans to be ideally suited to their local contexts. These refinements could include, but are not limited to, appropriate adaptations of RBIS that better meet their students’ needs.

We see pedagogical sensemaking as analogous to science sensemaking (Table I). We find this analogy useful for several reasons. First, the construct of science sensemaking has been well developed [58,59,64,65], and encompasses practices valued by the science education community [62,66,67]. Thus, it can provide a starting point for conceptualizing pedagogical sensemaking, particularly for researchers who are less familiar with the existing PD

TABLE I. The four primary learning goals articulated in the NRC 2007 report *Taking Science to School* [68]; examples from the literature of science sensemaking activities that would support each goal; and analogous examples from the teacher education literature of pedagogical sensemaking activities that would support these same goals in the context of instruction.

Goal from National Research Council [[68], p. 334] “Students who understand science:”	Science sensemaking example	Pedagogical sensemaking example
Understand, use, and interpret scientific explanations of the natural world	Students “apply general scientific ideas to their understandings of specific phenomena” (e.g., by defending an explanation of a specific event with a general scientific idea) [[62], p. 10].	Instructors consider how education research principles might apply to concrete examples of instruction [46,53,54].
Generate and evaluate scientific evidence and explanations	Students describe the nature of an event in detail, identify potentially key factors that caused it, and/or hypothesize about the processes by which it occurred [62].	Instructors notice students’ behaviors and disciplinary ideas during class [49,51,52,69,70] and hypothesize about how various instructional moves and peer interactions might influence students’ learning [40,46,53,54].
Understand the nature and development of scientific knowledge	Students develop models and representations of physical phenomena, then support and revise their models based on empirical evidence [67].	Instructors try out different instructional moves and gather evidence of students’ engagement and learning to iteratively refine their ideas about what constitutes effective instructional practices within a given context. [65,70–73]
Participate productively in scientific practices and discourse	Students “treat the information (e.g., data, scientific theories, personal experiences, etc.) they are using to justify and construct their knowledge products as requiring interpretation and synthesis” [[62], p. 11].	Instructors approach problems of practice as opportunities to learn with others, framing these problems as normal and inviting specification, interpretation, and appropriately constrained generalization [40,46,74].

literature. In Table I we use the goals articulated by the National Research Council [68] to articulate several categories of sensemaking and provide examples for each. For the pedagogical examples, we consider the natural world to be students’ ideas, engagement, and learning. We draw on the PD literature to support the potential value of these pedagogical activities.

Second, because science sensemaking is central to the pursuit of scientific research, faculty have likely gained significant experience engaging in science sensemaking in their professional work. In other words, faculty have gained useful knowledge and expertise from doing science, which they could draw on to improve their instruction. Our argument is related to Handelsman *et al.*’s vision [75] for a shift towards “scientific teaching.” Here, we argue that because science sensemaking is critical to doing science, processes akin to science sensemaking should be seen as a critical piece of scientific teaching.

Research related to science sensemaking can also help us start to consider what might support the emergence of pedagogical sensemaking in PD settings. Science education researchers have shown that instructors can promote sensemaking by asking open-ended questions, drawing out learners’ initial reasoning, and encouraging learners to question or build on their peers’ reasoning [70,71,73,76]. These facilitation moves could enable many learners’ ideas to be used as resources for everyone, which we would expect to see when rigorous sensemaking is occurring [67].

Research on teacher PD can lead us to identify other features of workshop sessions that could lead to pedagogical sensemaking specifically. As we mentioned previously, it is likely beneficial for workshop designers to create strong similarities to faculty’s local contexts. This could involve recreating practical situations that faculty likely come across in their everyday work, such as examining student work or experiencing and analyzing moments of classroom instruction, and working to build a sense of community around these activities [26,40]. Here, we emphasize that these activities not only have the potential to provide faculty with opportunities to draw on both familiar and new resources, they may also provide opportunities for faculty to engage in the activities described in Table I. Because we hope to identify some instances of sensemaking, we intentionally select sessions where faculty are engaged in these kinds of activities, in addition using this literature to support our analysis. We elaborate on our methodology in the next section.

IV. METHODS

Our research is set at the Physics and Astronomy New Faculty Workshop (NFW): a national, four-day workshop sponsored by the American Association of Physics Teachers, the American Physical Society, and the American Astronomical Society [15,17,18]. During our study, each iteration of the NFW was attended by 60–70 faculty, most within their first 1–3 years of teaching [18]. The workshop

itself is split into many 45–90 min sessions, most focused on teaching faculty about specific RBIS. Each session is facilitated by one (or more) of the 15–20 invited presenters, who are often the original developers of the focal RBIS.

We attended and video-recorded 42 sessions across two iterations of the NFW. The collection of *in situ* video data is consistent with our focus on the importance of interactions as a mechanism for learning (i.e., our desire to capture “mediating processes”). During this time, we were also simultaneously developing our real-time professional development observation tool (R-PDOT, [26]), which allows a user to capture the type and focus of faculty’s engagement during workshop sessions. Consistent with one purpose of the tool, we used preliminary R-PDOT coding (both “live” and from video) to aid in our selection process. Because we are particularly interested in whether and how faculty reason about RBIS, we first restricted our video selection to sessions that focused on specific, well-established RBIS (36 sessions), which was evident in the session titles. From these 36 sessions, we used the R-PDOT type of engagement coding to identify sessions that contained significant faculty talk (15 sessions). Moreover, we focus on sessions that include faculty participating in the “Analyzing Simulated Instructional Strategies” focus of engagement R-PDOT code. This code encompasses faculty reflecting on a shared experience of someone simulating instruction through watching video or role playing during the workshop, and is one indicator of possible pedagogical sensemaking.

Here, we exclusively focus on two sessions that provide the greatest opportunity for developing robust conjectures because of the significant similarities in their overall design. In particular, the two workshop leaders had communicated with each other about the session structure ahead of time and followed the same general design template. Moreover, these sessions occurred in parallel (i.e., at the same time) during the workshop, and the groups were randomly assigned prior to the start of the workshop (with 15–20 participants in each). Therefore, the two groups of faculty participants likely brought similar shared experiences from prior sessions and had a similar range of instructional expertise. The consistency in the setup of these sessions makes it likely that differences in the nature of faculty’s interactions can be accurately attributed to differences in facilitation. At the same time, we can check for differences in faculty’s contributions that might skew session norms (suggesting that the two participant groups importantly differ). We also look for similarities in faculty’s contributions across sessions to support our initial assumption that the two participant groups are similar.

Consistent with discourse analysis [77], we, along with a science education graduate student, iteratively analyzed these two video recordings by transcribing, watching, and rewatching each video both independently and as a group. We developed and refined tentative claims about the nature

TABLE II. Conventions for transcription, largely based on Ochs [78], and speaker labels.

Transcript notation	Meaning
\]	Overlapping speech
()	Tentative transcription, difficult to hear
[]	Descriptions of gestures and other non-verbal occurrences
<i>italics</i>	Narrative description of events
WL-A	The workshop leader in Session A
WL-B	The workshop leader in Session B
A, B, C, etc.	Faculty participants in Session A
L, M, N, etc.	Faculty participants in Session B
FP or FPs	Faculty participants in either session, difficult to determine the speaker

of faculty’s interactions and their relationship to the session design (primarily the workshop leaders’ facilitation moves) over a period of several weeks, until we reached a consensus [77]. For clarity, we describe our transcript conventions in Table II.

The primary goal of our analysis is to identify markers and causes of faculty engaging in doing school and pedagogical sensemaking. We do this to expand our understanding of both what these two modes of faculty engagement can look like, and what concrete facilitation moves may contribute to the development of each. We use the literature summarized in Sec. III as a starting point for characterizing our observations. For example, instances where faculty appear to be going through the motions without a particular purpose beyond appeasing the instructor would be identified as doing school, whereas instances where faculty seem to be critically analyzing pedagogical choices and considering alternatives (Table I) would be identified as pedagogical sensemaking. Similarly, we pay careful attention to the extent to which workshop leaders pose open or closed questions, as well as how they frame the session overall, and consider what kinds of discursive patterns this would support. As such, we pursue the following research questions: (1) *What are some specific markers of faculty engaging in doing school and/or pedagogical sensemaking?* and (2) *What structural features of the workshop session, particularly workshop leader facilitation moves, seem to contribute to cueing up or sustaining doing school and/or pedagogical sensemaking?*

V. ANALYSIS

A. Overview

These two parallel sessions center on teams of faculty trying out the implementation of Think-Pair-Share (TPS) (a RBIS that is roughly the same as Peer Instruction [79]). The design of these 1 hour sessions and an earlier set of 1 hour sessions (not analyzed here) are based on Prather

and Brissenden's "situated apprenticeship" [80] PD model [81]. In the earlier NFW session, small groups of faculty were asked to write a single multiple-choice question on an assigned physics topic. They were also told that they would practice implementing TPS the following day using the question they had written, and that they should prepare with their group.

We note that TPS as presented to faculty is comprised of highly specific phrases and steps. A workshop leader had modeled the strategy for faculty earlier in the workshop and made a case for the pedagogical value of its specific components. In those earlier sessions, faculty had acted as pseudostudents to respond to TPS prompts, while the workshop leader frequently paused to elaborate on the logic behind what they were doing. At points, the workshop leader asked all faculty participants to repeat the specific words and phrases in the TPS script out loud. Faculty were also given a paper "rubric" for reference (see Appendix A). Some of the rubric items assess the use of scripted phrases, such as "Did the presenter ask 'Do you need more time?' before going to the first vote?," while others are potentially more open ended, such as "Did the presenter appropriately direct the students to engage in discourse about their answer choices and explain their reasoning using a prompt that would foster an active discussion?"

In the sessions we analyze, groups of faculty collectively take on the role of a physics instructor to implement TPS, dividing up the "instructor" responsibilities between them. For instance, one group member might direct "students" (other faculty) to vote on the question for the first time, another group member would direct the pseudo-students to discuss with their peers, and so on. The remaining faculty act as both pseudo-students and critical friends for the "instructors." As critical friends, faculty are encouraged to "pause" the session at any point to critique the TPS implementation. According to this session design, the workshop leaders watch the TPS implementation and pause the instructors to make pedagogical corrections, but strive to fade out of this process over time by asking faculty to fill in the reason for the pause. At the end of each TPS round, a short amount of time is allocated for faculty to critique the physics question.

Here, we highlight two parallel episodes in each these "same" NFW sessions (referred to as Sessions A and B): (i) the workshop leader's initial framing of the session, and (ii) the first group's implementation of TPS and the related critiques. For interested readers, we present a third set of episodes surrounding faculty-initiated conversations about the potential affordances and drawbacks of using the exact same instructional script in every class in Appendix C.

B. Initial framing

At the start of each session, both workshop leaders describe the session guidelines listed above; however, differences in their talk suggest that characteristically

different norms may develop in each. Unpacking these introductory moments sets our expectations for what kinds of faculty engagement may emerge later on, and can help us to understand the extent to which other factors (beyond the workshop leader's talk) may also matter. Full transcripts are provided in Appendix B; here, we summarize our findings.

Aspects of both workshop leader A (WL-A) and workshop leader B (WL-B)'s introductory framing seem to cue up school-like norms, though WL-A's framing does so to a greater extent. The workshop leaders lay out similar rules and expectations for faculty's engagement. Both assert that faculty may find it difficult to follow the session rules, and state that they will pause the session themselves if faculty miss opportunities to do so. WL-B also explicitly directs faculty to use the TPS "rubric" and describes the precise time constraints of the session. These are potentially school-like directives that WL-A does not use. However, the nature of some of introductory language that WL-A alone uses could communicate even stronger school-like messaging. Only WL-A uses explicitly school-oriented words and phrases (e.g., "welcome to class" and "doing your homework") that might directly cue up faculty's ideas about acting as rule-abiding students in a traditional classroom. She also spends more time elaborating on what it might look like for faculty to break the rules: she cautions that if faculty do not pause the session at pedagogically appropriate moments, she might randomly call on them and thus cause them to feel "uncomfortable." In contrast, WL-B provides justification for why faculty might want to deviate from the rules to focus on physics instead of pedagogy, portraying this as a natural inclination faculty might have based on their previous experiences in the workshop. Moreover, only WL-A implies that there is a single, correct way of implementing TPS that faculty should be striving for, stating that trying out TPS in this environment allows faculty to "take the missteps" and "get it right" before trying it in their classrooms.

WL-A and WL-B also describe the distribution of responsibilities between themselves and faculty participants differently. WL-B's language seems to imply that everyone is in this together, e.g., she frequently uses the pronoun "we" to describe herself and the faculty participants, while WL-A deliberately articulates that faculty's responsibilities differ from her own. Both workshop leaders also mention a need to maintain a fast pace due to time constraints in this session, but they draw different conclusions about who should do this. WL-A states that faculty need to immediately explain why they paused the session in order to not "waste time," putting the burden on faculty, while WL-B implies that she will pay close attention to the time, thus putting the burden on herself.

C. First group implementation and critique

In these next two episodes, the first group of faculty in each session implements TPS and are paused and critiqued

on their implementation. Transcripts are provided in Tables III, IV, and V.

1. Session A

In Table III, we see that WL-A pauses the session almost immediately after the first group begins to present (lines A3-4). There is no evidence that faculty understand why

WL-A paused before she explains, or that they take away transferable pedagogical implications afterwards. From our perspective, there is little to no pedagogical reason for the pause based on what had occurred up to that point. Instead, we infer that WL-A is orienting to deviations from her exact vision for the session rather than reacting to a pedagogical misstep regarding TPS implementation. Moreover, it seems to us that faculty A's talk (line 3) did not represent an

TABLE III. Transcript of the first group of presenters being paused and critiqued in Session A. When faculty and WL-A offer scripted words and phrases as suggestions or critiques, these words and phrases are indicated by quotation marks. When these line numbers are referenced in the main text, they are prefaced with an "A."

	Faculty are seated and facing WL-A, who stands at the front of the room.
2	WL-A: We have just had a great lecture on simple harmonic motion and now your instructors are ready to ask you their questions. When it's your time, get up to the front of the class. I'll give you my pointer...
	<i>The faculty presenters stand and move to the front of the room. Faculty presenter E indicates that she did not anticipate going first. WL-A explains how to use the laser pointer.</i>
3	A [presenter]: Alright. So, I hope everybody enjoyed our fascinating lecture. [Advances the PowerPoint slide to show their question and turns to face the screen.]
4	WL-A: Pause.
5	B: Fascinating.
6	WL-A: Does he need to say anything?
7	C: Yes.
8	WL-A: Not really. The lecture just happened. You can say "I've got a question" you don't need to go into anything about your lecture.
9	D: Because you introduced.
10	WL-A: Yes.
11	D: And you know it's simple harmonic.
12	A [presenter]: So I have a question for you. [WL-A turns off lights]
13	A [presenter]: Oh, that's better.
14	A [presenter]: So without talking to your neighbor... actually, do any of you need more time? Okay, without talking to your neighbor, please form your own opinion about what the answer is. Just take a minute for that.
15	E [presenter]: Hold it to your chest so others can't see.
16	A [presenter]: Does anyone need more time? Alright, go ahead and vote on the count of 3: 3, 2, 1, go. [Faculty participants vote]
17	A [presenter]: Okay. Interesting. What I want you to do is turn to your neighbor and try to convince them that you're right. Just because you have the same answer, doesn't mean you're right or that you're done. Go.
18	WL-A: [after 2 seconds] Pause. You missed some key phrases.
19	F: "Explain your reasoning?"
20	WL-A: "Explain your reasoning."
21	G: Also, how much time we have.
22	WL-A: "You've got about..."
23	A [presenter]: Oh, yes.
24	WL-A: ... some period of time.
25	B: "About 30 seconds."
26	WL-A: And then what?
27	C: "Go?"
28	WL-A: "Go. Turn to your neighbor. Convince them that you're right." Say it with me,
29	WL-A and FPs: "Turn to your neighbor. Convince them that you're right."
30	WL-A: "You've got about \a min-]
31	FP: \a "30 seconds"]
32	WL-A: "30 seconds." Whatever. "Just because you both have the same answer doesn't meant that you're both correct, so make sure you explain your reasoning."
33	A [presenter]: Okay.
34	WL-A: Then "You've got about a minute. \a Go.]"
35	FP: \a "Go.]"

TABLE IV. Transcript of the first group of presenters being paused and critiqued in Session B. When faculty offer scripted words and phrases as suggestions or critiques, these words and phrases are indicated by quotation marks. When these line numbers are referenced in the main text, they are prefaced with a “B.”

	Faculty are seated and facing WL-B, who stands at the front of the room.
8	WL-B: Here's the set-up. We've just had a great lecture on simple harmonic motion and now they're ready to ask you their question.
	<i>Faculty presenters move to the front of the room, where the question they wrote is projected on a screen.</i>
9	N [presenter]: Hopefully you guys can see this. Since we've explained to you everything there is to know about simple harmonic motion. We're going to work on this short activity. Please take a few seconds to read the question and think about the answer, first on your own. Don't discuss with the person next to you. I'll give you a second to just read it. Think about it.
10	O [presenter]: Do you need more time? Okay.
11	FPs: Yes.
12	O [presenter]: 10 more seconds.
13	N [presenter]: Let's get ready to vote. I hope you all have your four color voting cards. We're going to vote on three, okay? One, two, three.
14	P [presenter]: Yeah people. Yeah, this is a little bit painful, because as I can see we have less than (15%) of the people choosing the right \answer.]
15	WL-B: \Pause!] Does anybody have anything to say?
16	FP: Interesting!
17	Q: Pause, pause.
18	FP: So you're not supposed...
19	WL-B: When you have less than 80%, you don't really want to tell them what the good or the bad is, you just want to move on to the getting them to talk.
20	P [presenter]: Okay.
21	P [presenter]: And then uh, well, what I would like to do is encourage you, mistakes just happen, alright. I'd like to encourage you to talk to your colleagues and try to convince them about your answer and then you're gonna go to another round of votes. To the count of three, one, two, three, and let's go.
22	FPs: [immediately] Pause.
23	P [presenter]: "Talk with your neighbors."
24	S: \Give a time.]
25	Q: "Talk to your neighbors," "give your reasoning," blah, blah, blah.
26	M [presenter]: Sorry?
27	Q: Oh I'm sorry.
28	R: We all have the same answer, we must be right.
29	WL-B: There was a pause there? What was the comment?
30	S: Give a length of time for us to discuss.
31	P [presenter]: So say like "You have \one minute"]...
32	FP: "You have 30 seconds"
33	P [presenter]: "... to discuss with your ..."
34	S: "You have 30 seconds," something like that, yeah.
35	P [presenter]: Good suggestion.
36	O [presenter]: Okay, 30 minute-, 30 seconds to discuss with your partner. Go!

authentic part of what he would do in the classroom. Instead, his words seem to mark a transition into the mock implementation: he simply reiterates the scene that WL-A had described.

This use of pausing seems to create confusion among faculty participants. For instance, soon after, faculty do not seem to understand WL-A's reasoning, quietly answering "yes" or not responding to her closed question, for which the expected answer was "no" (lines A6-8). Ultimately, faculty D seems to adopt a similar interpretation to ours by voicing the rules of the session (lines A9-11), which may have helped other participants to resolve their confusion. Regardless, because pausing for nonpedagogical reasons deviates from the espoused session rules, and because

WL-A paused the session almost immediately, it seems unlikely that faculty would have paused the session this quickly themselves.

As the session continues (Table III, lines A12-35), WL-A's pause and critique of "You missed some key phrases" lead into what seems like a school-like memorization game. Faculty are prompted to recite and listen to words and phrases from the prescribed script without any articulated pedagogical justifications for why these words and phrases would be consequential for students (lines A18-35). Several of these turns of talk are well characterized by an initiate-respond-evaluate (I-R-E) discursive pattern (e.g., lines A26-28). WL-A then launches into reciting the whole script, prompting faculty to "say it with

me” (line 28), and faculty respond by fading in and out of filling in the blanks (lines A29-35). We also note that none of the “correct” phrases that the presenter said are acknowledged. In contrast, WL-A reelicits and restates several of the prescribed phrases that faculty A already articulated, obscuring opportunities for faculty A to be recognized as competent.

Overall in this episode, we note that only WL-A pauses the session, which, together with the introductory framing, indicates that the faculty who are acting as pseudostudents and critical friends did something wrong. This seems fairly unavoidable for faculty, as WL-A pauses the session at times when it would have been unlikely for them to do so. These pauses are followed by closed discussion or lecture that points to a single correct way of implementing TPS. Little or no pedagogical justification is provided; instead, there are few if any detours from the encouragement of rote memorization.

2. Session B

Transitioning to the transcript for Session B (Table IV), we see that WL-B also initiates the first pause of the session (line B15). She invites faculty to contribute, which some begin to do (lines B16-18), but then answers her own question by articulating a directive associated with the TPS script (line B19). While faculty’s talk is limited during this

critique, the beginning phrases and revoicing of pause provides some evidence that they agree that a pause was appropriate, and might agree with WL-B about the correction.

Continuing on in the transcript (Table IV, lines B21-36), we see that many faculty participants voice the second pause of the session (line B22) and contribute subsequent critiques. WL-B only speaks once, using her authority to invite a faculty participant to revoice his contribution so that it can be heard by other participants (line B29). This intervention leads faculty to narrow in on a single suggestion, which two of the presenters take up and use to resume their mock implementation. This shows some autonomy developing among faculty, as the presenters determine the duration of the critique and whether to accept the suggestion without explicit direction from WL-B.

When it comes to the substance of faculty’s talk, we perceive a shared sense that saying all the words in the prescribed TPS script is desirable. Those who speak make similar suggestions about what words to say, typically without elaboration or debate, and a presenter asserts that there is value in these suggestions. A correction that is very close to the presenter’s words but more precisely aligned with the script (“talk to your neighbors” as opposed to “talk to your colleagues,” line B25) and a participant’s “blah blah blah” (line B25) might also demonstrate a focus

TABLE V. Continued transcript of the first group of presenters being paused and critiqued in Session B. As earlier, when faculty offer scripted words and phrases as suggestions or critiques, these words and phrases are indicated by quotation marks. When these line numbers are referenced in the main text, they are prefaced with a “B.”

	Before this segment begins, faculty who are acting as pseudostudents discuss the physics in small groups while some of the presenters circulate the room. We resume as the presenters regain the attention of the other faculty.
37	T [presenter]: Alright. Now that you’ve had some time to think about it and discuss with your neighbor, on three we’re going to do another vote. Get ready to vote. One, two, three. Alright. Much better. The correct answer was ...
38	FPs: C.
39	T [presenter]: Yes, exactly. That’s because if a harmonic oscillator has the same mass and the same type of spring. They have the same
40	FPs: Frequency, period, frequency.
41	T [presenter]: Ah, right. Same frequency, same period. That’s really the same thing. Alright. Well great!
42	WL-B: Great job.
43	Q: Thank you. [starts clapping, other faculty clap]
44	WL-B: That was great. Thank you for being the first volunteers. Any comments about the implementation when you’re looking through these questions [motions looking at a rubric]?
45	U: I think the answer E is a little bit confusing. They will not cross.
46	WL-B: Okay, so we’ll get to the question in a minute.
47	U: Oh, okay.
48	WL-B: No that’s okay. It’s because it’s easy to go straight to the question, I want to make sure we’re spending enough time on the implementation. \U: Okay.] So how they did the Think-Pair-Share.
49	V: We already paused them, right?
50	WL-B: Yeah. You feel like you already said everything there was to say?
51	Q: Could probably be a little bit faster, I’m not sure. The whole thing. Less time talking. That depends on the person who does it.
52	M: When we were encouraged to convince each other there was no statement made about having the same answer. So like our group we all had the same answer and we were kinda like “Yeah we’re all right.”
53	O [presenter]: Ohh, that’s right.
54	M: “Just because you have the same answer doesn’t mean that you’re right.”

on saying the exact script in its entirety, and a potential lack of attention to the meaning behind what the pseudoinstructors said.

Notably, however, one faculty participant provides pedagogical justification for an implicit suggestion: faculty R takes on the role of a pseudostudent to play out a potential negative consequence of not saying the scripted phrase “just because you have the same answer, doesn’t mean you are both right” by stating “we all have the same answer, we must be right” (line B28). Thus, even though no one contests a lack of pedagogical justification when it is absent, there is evidence that at least some faculty are thinking logically about the TPS implementation and not just filling in memorized words, and that they perceive this to be an appropriate activity here.

In order to illustrate further how pedagogical sense-making seems to be developing in Session B, we present an additional piece of transcript in Table V. Considering WL-B’s contributions first, we notice that she praises and thanks the instructors before eliciting additional evaluation from other participants (lines B42, B44). She is also diplomatic about guiding faculty to comment on the implementation instead of the science content or the question itself (lines B46, B48). As in her initial framing, she expresses empathy for faculty’s desire to talk about the content, framing this as a natural inclination. When a faculty participant questions whether there is anything left to talk about with respect to implementation, WL-B persists in eliciting faculty’s pedagogical ideas and invites them to judge whether or not there is more to discuss (lines B49-50). Her prompt initiates a faculty-led critique.

When it comes to faculty’s interactions, one faculty participant reiterates the pedagogically rich critique that we noted in earlier on, which was not explicitly acknowledged by others at that time. Echoing faculty R’s earlier, implicit reasoning (line B28), faculty M recalls his experiences in a student role in order to communicate that it was easy to assume his group was correct about the physics when they all agreed on the multiple choice answer (line B52). It is only after providing this pedagogical justification that he recounts the precise relevant line from the script (line B54). We consider this a strong example of faculty engaging in pedagogical sensemaking around this prescribed instructional strategy.

3. Comparison of Sessions A and B

While participants’ interactions in these two sessions are characteristically different during the first round of TPS implementation, we are also struck by the similarities in the presenters’ actions and talk when enacting TPS, and in the kinds of critique that many faculty participants offer. For instance, the first few words spoken by the presenters are almost identical. Likewise, presenters in both sessions follow the TPS script to similar extents when directing the pseudo-students to talk with their neighbors about the

physics: both include some of the prescribed phrases and omit some pedagogically consequential directives like “explain your reasoning.” Across both sessions, we also notice that many (or all) faculty tend to orient to what is “supposed to” be said, do not elaborate on the pedagogical justifications behind these words or how they are importantly different from the presenters’ words, and do not interrogate each others’ logic. In this way, pointing out deviations from the prescribed script and filling in the correct words is often treated as sufficient during the critique process; there is little accountability among faculty participants for doing otherwise.

These strong similarities suggest that the workshop leaders are faced with the same situation, and their actions seem to shape the important differences in faculty’s interactions and contributions that we observe. In Session B, faculty quickly take over the critiquing process themselves, and some do provide pedagogical justifications for the scripted phrases in TPS. On the other hand, in Session A, faculty have a more passive role and only contribute memorized words and phrases. For instance, faculty in Session B take up an opportunity to initiate the second pause of the session and critique the presenters themselves, while faculty in Session A are presented with a parallel opportunity and do not, instead waiting for WL-A to pause the implementation herself. We can potentially trace this back to differences in the workshop leaders’ initial framing (described earlier) and in how the workshop leaders react to the first few words spoken by the presenters (described in this subsection). Here, we notice that WL-A chooses to pause the session at this early point, seeming to orient to a deviation from her vision for the session rules rather than a pedagogical lesson, and faculty seem to struggle to follow her reasoning. In contrast, although WL-B also initiates and elaborates on the first pause of the session, she does so at a later point where the reasoning seems clearer to us and to faculty, which may have fostered a growing sense of ownership over the process among faculty.

These contrasting norms are maintained as the two sessions continue after this second pause. During the critiquing phase, WL-B says very little and lets faculty discuss among themselves, only intervening to draw attention to one faculty participant’s justification and thus help to focus the group on one idea. WL-A maintains control of the critiquing process and begins a closed discussion with faculty participants, where she only asks faculty to contribute short words and phrases that she evaluates for correctness.

Critically, these differences in facilitation seem to lead to a situation where faculty only engage in pedagogical sensemaking in Session B.

VI. DISCUSSION

Our analysis reveals specific mediating processes consistent with both doing school and pedagogical sense-making. As shown in Table VI, the processes that we

TABLE VI. Observed markers of faculty engaging in doing school and pedagogical sensemaking.

Kinds of mediating processes	Doing school	Pedagogical sensemaking
Orientation to the workshop leader	Faculty defer to the workshop leader's authority and judgment, and ask questions to try to figure out what behaviors are desirable.	Faculty start to take over the workshop leader's initial role in the session, gaining ownership over the critiquing process.
Accountability to sensemaking norms	Faculty offer memorized words and phrases without justifying their value or purpose, and do not ask for pedagogical justification when it is absent.	Faculty reason about the pedagogical value of memorized phrases. (<i>Not observed: Faculty hold each other accountable for providing pedagogical justification.</i>)
Use of observations or evidence	Faculty compare observations of simulated instruction to "correct" instructor moves without considering simulated student behaviors.	Faculty construct pedagogical arguments using their observations of simulated instructor and student behaviors.
Development of testable hypotheses	Faculty do not generate or articulate any hypotheses about what student behaviors may result from various instructional moves.	Faculty hypothesize about how students might respond to different instructional moves, such as how these moves might shape students' conversations.
Structure of faculty contributions	Faculty contribute short words and phrases, often filling in the blanks for the workshop leader.	Faculty often speak in complete sentences and respond directly to their peers.

associate with doing school include faculty passively deferring to the workshop leader's authority, evaluating their peers' instruction based only on "correctness," and offering memorized words and phrases without pedagogical justification. In contrast, the processes that we associate with pedagogical sensemaking include faculty developing ownership over the critiquing process, using observations of simulated student behaviors to develop pedagogical arguments, and reasoning about the potential consequences of various instructional moves. Through engaging in these processes, faculty are beginning to robustly analyze the prescribed implementation steps by providing evidence-based hypotheses to support their claims and debating with their peers using logic that is sensible to them.

We observe faculty engaging in doing school primarily in Session A, while we see faculty engaging in pedagogical sensemaking in Session B. Because of the highly similar nature of these two sessions (both the overall design and the initial behaviors of faculty participants), we claim that these differences in faculty's interactions result from differences the workshop leaders' facilitation. We describe the specific, contrasting facilitation moves we observed in Table VII.

Guided by Sandoval's framework [27], we can synthesize our analysis with the following pair of design conjectures (also shown in Fig. 2).

First, if the basic session structure follows Prather and Brissenden's model [80] and the workshop leader's facilitation moves focus on

- enforcing predetermined behaviors that seem opaque to faculty,
- highlighting the workshop leader's own authority and expertise, and
- evaluating the correctness of implementation based on alignment with a prescribed script,

then faculty will engage in doing school, going through the motions without articulating any underlying pedagogical logic.

On the other hand, if the basic session structure again follows Prather and Brissenden's model [80] but the workshop leader's facilitation moves focus on

- responding to and gently navigating faculty's incoming expectations and affective responses,
- developing a sense that "we're in it together" where power differentials are minimized, and
- encouraging norms for exploring alternative instructional moves and providing pedagogical logic behind implementation choices,

then faculty will begin to engage in pedagogical sensemaking, articulating implications of instructional choices for student engagement and learning.

We hypothesize that several aspects of the overall session design that were the same in both sessions can serve as resources for the development of pedagogical sensemaking, provided that the workshop leader's facilitation also encourages this. For instance, faculty in Session B would not have used their own observations of simulated student behavior to support their arguments if they had not first engaged in a role-playing activity. More broadly, both sessions nominally center on creating opportunities for faculty to notice and critique aspects of each other's instruction. In this way, the pedagogical sensemaking that we see during Session B is consistent with, and thus supported by, the overall session design.

On the other hand, the effects of other aspects of the session design are more ambiguous. Although almost all of WL-B's facilitation moves seem to encourage sensemaking, we again note that faculty enact some school-like behaviors in both sessions. In particular, faculty in both sessions treat memorized words and phrases as sufficient

TABLE VII. Observed workshop leader facilitation moves (part of the session embodiment) that seemed to contribute to faculty engaging in doing school or pedagogical sensemaking as in Table VI.

Kinds of facilitation moves	Doing school	Pedagogical sensemaking
Introductory language	Workshop leader describes a single model for quality implementation and uses explicitly school-like words	<i>n/a</i>
Orientation to “rule breaking”	Workshop leader implies that faculty are likely to break the session rules when setting and enforcing them.	Workshop leader acknowledges that following the session rules may “feel a little weird” to faculty.
Expectations for session responsibilities	Workshop leader states that faculty responsibilities in the session are different from their own responsibilities.	Workshop leader indicates shared ownership for following the session rules.
Demonstration of critiquing norms	Workshop leader treats articulation of memorized words and phrases as sufficient implementation critiques.	Workshop leader hypothesizes about student behaviors that might justify a variety of instructional moves and encourages faculty to do the same.
Scaffolding of faculty participation	Workshop leader asks faculty to fill in implementation critiques at times when they are not likely to appear competent.	Workshop leader sets faculty up to be successful at analyzing instruction by choosing an accessible example and eliciting their responses.
Structure of interactions with faculty	Workshop leader asks exclusively closed questions and elaborates on faculty’s short responses, sometimes interrupting them.	Workshop leader asks some open questions and allows faculty to speak in complete sentences.
Nature of feedback to faculty	Workshop leader infrequently praises faculty, primarily focusing on repairing deviations from prescribed words.	Workshop leader frequently praises and encourages faculty.

critiques of instruction, neglecting to hold each other accountable when no justification is articulated.

It is unclear to what extent this inclination to do school relates to faculty’s prior experiences within the NFW (or outside of it), as opposed to their experiences within this particular session. However, some of the aspects of the session design that we observe in our data could have contributed to faculty doing school across sessions. For instance, we wonder about the influence of the highly scripted instructional strategy

on faculty’s interactions, particularly in coordination with the numerous closed questions on the TPS rubric that seem to communicate a correct implementation. Beyond this, both workshop leaders noted their perception of strong time constraints for the session overall, which may have had a role, directly or indirectly, in constraining faculty’s talk.

The limitation in our ability to diagnose the influence of design features that were common across sessions naturally results from our use of contrasting cases. Intentionally

FIG. 2. A summary of our design conjectures, which take the form: If a workshop session is embodied in this way, then we expect to see these mediating processes emerge.

modifying these potentially less desirable design features could present a path forward for additional design-based research on this session.

VII. CONCLUSIONS

Because typical workshop sessions that we have seen focus primarily on increasing faculty's awareness of RBIS, a goal which has been largely achieved [15,16,18], we argue that it is important to investigate more unusual sessions that have the potential to promote faculty's sustained engagement in pedagogical sensemaking. In particular, workshop sessions like this would enable faculty to draw on resources that are accessible in their everyday work and model collaborative, reflective interactions that faculty could engage in at their home institutions.

A variety of activities could match these criteria. Such activities may include faculty simulating instruction, working through research-based curricular materials, creating and analyzing student tasks, watching classroom video, and discussing case studies that illustrate student perspectives [26]. However, highly interactive workshop activities like this may have pitfalls: we argue that faculty may either go through the motions and seek correct answers (do school) or engage in pedagogical sensemaking when presented with opportunities to analyze instruction. Only pedagogical sensemaking would provide the foundation for faculty's future learning for which we advocate.

In this paper, we investigate a workshop session design in which faculty are asked to simulate and critique the implementation of a particular RBIS [80]. Our analysis of two sessions that follow this overall design both confirm its promise and reveals the importance of the workshop leader's facilitation. In one session, faculty seem to exclusively engage in doing school, while in the other, we see faculty demonstrating some aspects of pedagogical sensemaking. We illustrate these differences by drawing attention to specific markers of each. We attribute these differences in faculty's engagement to differences in facilitation such as the workshop leaders' orientations towards adoption versus adaptation of this instructional strategy (explored further in Appendix C), and how the workshop leaders position themselves relative to faculty participants in the session.

Our analysis strengthens our initial, theoretical argument that faculty's perceptions of their situation will importantly influence their learning. Our data suggest that many physics faculty have the capacity to engage in both doing school and pedagogical sensemaking, and that workshop leaders who are attuned to these different modes of participation may be able to help faculty shift into sensemaking. However, we note that we only have limited evidence of individual faculty participants' thinking. We foreground conversations that provide evidence of an emergent, collective framing, and do not seek evidence of variations in what individual faculty may have

experienced. In the future, the use of complementary methodologies like stimulated recall interviews could enable researchers to develop stronger evidence of the extent to which visible framings are shared across participants.

While the results of our current study provide some useful insights, there is still much left to explore. As we have demonstrated here and elsewhere, qualitative, case study research can provide direct guidance to workshop leaders and other change agents. Specifically, this kind of work can both expand their understanding of what it can look like for faculty to engage in doing school and pedagogical sensemaking, and provide them with insights about how to foster one and mitigate the other [23,56]. In this work, we have only captured a few aspects of what we suggest could comprise pedagogical sensemaking. Some of these aspects of pedagogical sensemaking could occur in other workshop sessions, while others may only occur over longer timescales and thus would require researchers to investigate faculty's engagement in sustained instructional change efforts. An increased understanding of how and why faculty engage in pedagogical sensemaking in a variety of contexts could provide guidance in how to design for and support it. Conversely, doing school may have additional features that future researchers could identify. A greater awareness of the nature of these potential impediments to sensemaking could illuminate additional opportunities to improve faculty learning environments.

Thinking more broadly about future research directions, there could also be other kinds of mediating processes that are consequential for other kinds of faculty outcomes. For example, if faculty develop new social relationships with colleagues and discuss shared challenges, they might experience an increased sense of belonging [82] in their professional community. Or, if faculty become affectively engaged in creating and iteratively refining instructional materials, they might develop a sense of pride [83] related to their teaching. It would be valuable for our community to pursue this type of modeling of faculty learning. We hope that moving forward researchers will continue to learn from observing current professional development efforts and support facilitators in considering how their findings could inform future efforts.

ACKNOWLEDGMENTS

The authors would like to thank the Physics and Astronomy New Faculty Workshop leadership team, particularly Edward Prather, Robert Hilborn and external evaluator Stephanie Chasteen, and the workshop leaders and faculty who participated in this study. We would also like to thank all the members of the Center for Astronomy Education Tier I Teaching Excellence Workshop leadership team who participated in our pilot research and developed this session design, as well as the University of Maryland Physics Education Research group,

particularly Hannah Jardine, Andrew Elby, and Edward (Joe) Redish. Finally, we would like to thank the undergraduate students and AAPT staff who helped to ensure that our data collection went smoothly. This work is supported by funding from NSF-DUE 1431681.

APPENDIX A: THINK-PAIR-SHARE IMPLEMENTATION RUBRIC

A Think-Pair-Share implementation rubric was provided to all participants at the start of the workshop, as part of a packet of workshop materials. Below, we present the text from this handout verbatim.

Implementation Items:

- Did the presenter refrain from reading the question to the students?
- Did the presenter allow time for the students to read and think about the question?
- Did the presenter ask Do you need more time? before going to the first vote?
- Did the presenter get the students to vote simultaneously and anonymously?
- Did the presenter appropriately choose to disclose the distribution of answers from the first vote?

- Did the presenter appropriately direct the students to engage in discourse about their answer choices and explain their reasoning using a prompt that would foster an active discussion?
- Did the presenter use a prompt about the amount of time students would be allowed to collaborate as a way to encourage discussion?
- Did the presenter observe the level and type of student discussions so as to appropriately gauge the amount of time students would need to defend their votes and explain their reasoning?
- Did the presenter provide a prompt about time so students knew their time to discuss would shortly be coming to an end?
- Did the presenter get the students to vote a second time simultaneously and anonymously?
- Did the presenter debrief the final vote results with the students in a pedagogically useful way?

Question Items:

- Did the question serve as a good vehicle to promote a cognitively engaging and conceptually rich discussion amongst the target population?
- Were the answer choices distinct, and representative of likely student conceptual and reasoning difficulties, which a real student might vote for?

APPENDIX B: TRANSCRIPT OF THE WORKSHOP LEADERS' INITIAL FRAMING

In Tables VIII and IX, we show transcript of the first few minutes of the two parallel workshop sessions that we focus on. Our analysis of the episodes captured here is presented in Section VB of the main text.

TABLE VIII. Transcript of WL-A's initial framing of the TPS implementation session, i.e., the first few minutes of Session A.

- 1 WL-A: Hi, welcome to class. I need to lay some ground rules. We are going to have one group up presenting. You've presumably practiced. I'm going to believe all of you did your homework and you've decided on who is doing what part of implementation. When there is a group up there presenting, it is our job—not mine, yours—to pause them if they have missed a step in the implementation that [a workshop leader] demonstrated and that you had a link provided for a “how to” guide on. If you pause someone, don't look at me and wait for me to say, “Well why did you pause them?” You paused them. You have a reason. Just say, “Pause, you should have blah blah blah.” Okay? Because we don't want to waste any more time on that.
- There are two reasons why critiquing is important: it's important for the people who are presenting, so that they have the time here in a loving and supportive and caring environment, in the safety of others, to practice, stumble, take the missteps and try it over again, get it right, before doing it in front of students. That is a very powerful thing for you to be able to go home with. You will feel more comfortable and secure in trying this in your class when you go back home.
- For those of us that are doing the critiquing, you are at your highest level of understanding something when you are able to synthesize what's happening and to assess and evaluate it. So that's what you're supposed to be doing. If I don't hear you pausing people, I'll pause you and I might just randomly point at someone and say, “You say why I paused them.” That's uncomfortable. I don't want to do that. It's uncomfortable for all of us. Usually what happens if I'm having to pause you is that you are spending too much time thinking about physics. That's your focus, is getting the question right. That's not the reason why we are here. The reason why we're here is to be students for our teachers and to be critical friends for our colleagues. Any questions before we get going?

TABLE IX. Transcript of WL-B's initial framing of the TPS implementation session, i.e., the first few minutes of Session B.

-
- 1 WL-B: This is Think-Pair-Share. You should be in whatever room you were in for that yesterday. Does everybody have a rubric?
 2 L: How do we know whether we have a rubric?
 3 WL-B: Rubric says, "Rubric for Think-Pair-Share implementation." I want at least one in each group. You can share.
 4 L: I don't think I have this. I don't have it.
 5 WL-B: Does everybody in your group have one? If you don't have one in your group I can give you one. Everybody found their group? Awesome.
 6 M: Are we filling these out or something?
 7 WL-B: No. Here's what's going to happen. We have 10 minutes for each group and we're already 9 minutes behind. I will keep us tightly to the clock. What will happen is that for example, simple harmonic motion will come up here and they will present their question and you guys need to use the rubric to help you remember when to yell pause. They're going to do their Think-Pair-Share question and you should yell pause whenever these questions, whenever we're not all doing the optimal job that we can do. There will be 8 minutes for the presentation, there will be 8 minutes on implementation and then in the last two minutes we'll talk about the content of the question. That may feel a little weird because you spent so much time thinking about that content last time. But this is all about the implementation. I will yell pause if you don't. But remember we're all here to give constructive criticism and to help each other get better at this. Does anybody have any questions?
-

APPENDIX C: ANALYSIS OF CONTRASTING DISCUSSIONS ABOUT ADOPTION VERSUS ADAPTATION

We suspect that workshop leaders are often faced with decisions about how strongly to push for direct adoption of research-based instructional strategies. Particularly relevant for this analysis, we have noticed through all of our

observations of the NFW that some participants will question the highly scripted nature of TPS. Thus, it is unsurprising to us that a faculty participant in each of our focal sessions did so. Because this event was both common across sessions and a common situation that some workshop leaders might be faced with, here, we provide our analysis for interested readers.

TABLE X. Transcript of a conversation about the scriptedness of the TPS script in Session A.

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- 36 WL-A: Okay, I would like everyone to pull their rubric out if you don't already. I should have had that out. There's some talking... there's questions that you're supposed to be using as a reference for pausing. I just want you to remember that they're there.
 37 H: Do you use these exact rubrics for every single question that...
 38 WL-A: Absolutely.
 39 H: You do?
 40 WL-A: How do you think I know them so easily? I think they just come out of my mouth.
 41 H: I find it hard that \it's like a scripted...]
 42 WL-A: \Well, you've never used it before.] It is. It is, but it projects. It's been, we've field tested in our own classes trying many many many many different phrases. And we're not saying you need to use... in fact, [a workshop leader] said it many times yesterday. We're not saying you need to use these words at your home institution. You do whatever you want. We want you to have an experience using the words that we know absolutely motivate your students to have the conversation that you want efficiently, on board, doing it, and gettin' 'er done.
 43 H: Because, it seems like there's a lot of good parts to it...
 44 WL-A: Yes.
 45 H: explaining yourselves and...
 46 WL-A: There are.
 47 H: ...key words, but scripting is difficult for everyone.
 48 WL-A: It is. But I didn't... I mean, it evolved. I didn't know it, right? And there's all sorts of people who didn't... Again, I'm saying you don't have to remember that, but having good words to use and getting your students accustomed to that experience... it's the same all the time. I'm reminded the same way all the time. I know what my expectations are all the time, is a good thing.
 49 I: Do you have the script online somewhere or do we have to (inaudible).
 50 WL-A: No, in fact, the implementation... there was a piece of paper that I handed out yesterday that had a link on it. It was blue. And it's on...
 51 H: It's also on the...
 52 WL-A: And it's on...
 53 FP: The handout.
 54 H: PhysPort website.
 55 WL-A: It's on the PhysPort website and it's on the CAE website.
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TABLE XI. Transcript of a conversation about the scriptedness of the TPS script in Session B.

55	W: So I have a meta question. Throughout the semester all the lectures will be like that, and I'm wondering if, will the students will get sick of it eventually if we just do this religiously, say the same thing each time. "You have 30 seconds," or "the fact that you have the same answer doesn't mean that you..." each time saying this might get old quickly I feel.
56	WL-B: I think if you're getting the sense that they know all of this very, very well [W: Mhm.] then making that shorter and figuring out what's the key part like, "Convince them you're right. Remember to..." you know, that "if you have the right answer you don't know, go." That's okay. Right now it's a script to get all the parts in [W: Yeah, sure.], but if it starts to be absurd to you it's probably absurd to them.
57	O: After the (third week) I don't think you have to say any of that I think just "Go!"
58	R: It's comfort to them though.
59	O: Once in awhile.
60	P: Sometimes routine is good.
61	X: I think [another workshop leader] would disagree. I think [other workshop leader] would say [WL-B: Do it every time?] that at least on the convince your neighbor part he always wants to build in that (inaudible) for that tension. That's what he was saying.
62	WL-B: I would say you still need to follow all of these questions so if they're not feeling a sense of urgency, if they're not feeling that they need to convince people then you are not saying the right thing.
63	Y: I sometimes underline, I often tell them, "If I don't hear arguing you guys aren't doing your job."
64	FP: I don't think [other workshop leader]'s style will necessarily work for everyone. Not everybody has exactly the same classroom presence and...
65	WL-B: [And [other workshop leader] says that as well.]
66	FP: [The same kind of relationship with their students.] I think you can do all these things without inciting a riot. You know what I mean? Without feeling the need to give your students pitchforks.
67	WL-B: Right. There does need to be a sense of urgency to get them moving [FP: Yeah, definitely] but you don't have to be [other workshop leader] to do this job.
68	WL-B: Okay. Any questions in our two minutes about the question?

As shown in the transcript in Tables X and XI, a faculty member in each session spontaneously raises a concern about the scripted-ness of this instructional strategy. These faculty participants suggest that there may be reasons to adapt or modify the TPS script, and the workshop leaders and other faculty respond.

Briefly stated, WL-A responds by strongly advocating for adoption based primarily on the effectiveness of TPS in the developers' classrooms (including her own), while WL-B encourages thoughtful adaptation based on observed student behaviors. More precisely, WL-A acknowledges that adaptation is possible, but implies that it is risky and might result in students not having desirable conversations or not starting these conversations efficiently. Accordingly, she focuses on encouraging faculty to persist in trying out this exact script without any modification. While she does provide limited pedagogical logic, briefly describing ways that students would benefit from an instructional routine, she leans heavily on the argument that the developers met with positive outcomes to advocate for use of the prescribed script. In contrast, WL-B positions faculty as knowledgeable about how their students are responding and describes some intuitions that might lead faculty to shift their

instruction. By doing so, she supports faculty in thoughtfully adapting TPS and communicates that she thinks they are capable of making these pedagogical judgments.

Interestingly, we note that in both sessions, there is disagreement around whether TPS should be used in its highly scripted form. In Session A, the faculty participant who asks the question makes a bid for adaptation, suggesting that one could identify and use key phrases from the script instead of saying all of the words, which is not supported by WL-A. In Session B on the other hand, a faculty participant questions strict adoption and, unlike in Session A, provides pedagogical justification by suggesting that students might "get sick of" the script. WL-B initially agrees with him and suggests that adaptation based on reducing the script to what seem like key parts and assessing students reactions would be appropriate. However, in this case, some faculty disagree with her, taking a similar stance on adoption to WL-A in the other session and appealing to authoritative sources such as the developer's ideas. Following this, WL-B ends up taking more of a moderator role in faculty's debate with their peers, lending weight to their ideas and drawing attention to the general pedagogical foundation beneath what they are saying.

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