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Factors of Sensemaking Affecting Engineering Faculty's Decision to Use the In-Class Cognitive Engagement Survey*

ALLYSON J. BARLOW, BEN LUTZ, NATASHA PEROVA-MELLO, KATHLEEN QUARDOKUS FISHER and SHANE BROWN
Oregon State University, Corvallis, OR, USA. Corresponding author: Allyson Barlow. 101 Kearney Hall, 1491 SW Campus Way, Corvallis, OR, 97330, USA. E-mail: ironsida@oregonstate.edu

While engineering education researchers have developed research-based instructional strategies (RBISs) to assist faculty in their teaching effectiveness and thereby student learning, uptake of these strategies remains challenging due to a wide range of faculty concerns. One established way to address such concerns is to involve them in the research and development process. In this study, we developed a tool to measure in-class cognitive engagement, an attribute most faculty recognize as crucial to student learning and used sensemaking as a framework to interpret faculty feedback on the survey's development. This tool, the In-Class Cognitive Engagement (ICCE) survey, was presented to faculty in an interview setting where they discussed and projected student interpretations and responses to survey items. We applied a sensemaking framework to the interview analysis to explore the ways participants might adjust or adapt to a new way of interacting with the world. In this case, the new interaction was the introduction of a cognitive assessment—the ICCE survey—into their classroom. We present findings that demonstrate the utility of sensemaking core properties to understand how faculty come to conclusions about the usefulness of the ICCE survey in their classroom. Implications of these findings include continued work directly with faculty to provide them with appropriate contextualization of RBIS-related instruments and broader use of technology (such as dashboard) to synthesize results to provide both timely and meaningful feedback to faculty.

Keywords: diffusion; adoption; faculty attitudes; engagement

1. Introduction

There are a multitude of research-based instructional strategies (RBISs) that have been established in STEM Education, many emerging from the critique of traditional approaches to teaching and learning. Such critiques have motivated movement towards student engagement and active learning in engineering classrooms. This movement is evident in studies of cooperative learning, problem and project based learning, service learning, and learning communities, emphasizing the importance of active engagement [1–3]. Freeman et al. found that "active learning increases examination performance by just under half a standard deviation and that lecturing increases failure rates by 55%" [4, p. 8412]. Additional work by Chi and Wylie posits that the in-class behavior of students is indicative of their cognitive engagement, and thereby complex understanding of the material [5]. With ties to both student performance and complex understanding, developing strategies to enhance in-class engagement remains an active area of interest for engineering educators.

While significant effort has been expended to develop further and to implement RBISs in broad educational contexts, there remains a gap between the availability of RBISs and their implementation by engineering faculty in postsecondary classrooms [6]. Research suggests faculty and educational administrators are often sources of resistance to change, in part because they are rarely included in the development process and testing phase of educational innovations [7–9]. Relatedly, faculty as a whole cannot be seen as a homogenous decision-making group: Lattuca [10] suggests it is often faculty's own motivations, decision-making processes, commitments, and receptions surrounding innovations that propel them to make changes in their classes. Both faculty's historical resistance towards RBIS-related change and the important role their perceptions play in their decisions to adopt RBISs suggest a need for RBIS development models that make use of faculty input.

The present work is part of a larger project investigating the engagement of college students along cognitive and social dimensions, both in and out of class [11]. The purpose of this paper is to explore faculty perceptions surrounding the potential adoption of a research-based survey instrument. The study presented here focuses on the In-Class Cognitive Engagement (ICCE) survey. The goal of the ICCE instrument development process is to produce an instrument that is both valid and reli-

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able, and, perhaps most importantly, adoptable by STEM faculty. Here, an adoptable survey is defined as a survey that faculty interpret as both *useable* given their classroom context and *useful* for understanding the cognitive engagement of their students. To address concerns of adoptability, faculty were actively involved in the development process of the instrument. Faculty participants were considered both stakeholders in and co-creators of the instrument discussed herein, recruited not only to implement the ICCE survey in their courses, but also to discuss its meaning in their context. A sensemaking framework guided the interpretation of faculty perceptions. Broadly defined as developing a set of ideas based in plausible explanations [12], sensemaking occurs when a current experienced state is different than the expected state [13], in this case asking faculty to implement the ICCE survey in their course and reflect on its usefulness.

2. Literature review

Central to this study is work surrounding both faculty adoption of RBISs and the sensemaking framework. The literature points to several gaps in our understanding of faculty sensemaking as it pertains to educational innovations. First, we discuss faculty adoption literature in a broad sense. Next, we focus more closely on current limitations of RBISs to transform undergraduate education, pointing to a need for faculty involvement in the development of classroom tools. Last, we define and operationalize for this study *sensemaking* in terms of seven core properties.

2.1 Adoption

Faculty adoption of RBISs is a key component of positive educational change and innovation yet remains a consistent challenge for researchers and educators. Recall that for the purposes of this study an *adoptable* instrument is defined as being both *useable* given classroom context and *useful* for understanding students. The field of change research investigates the dissemination of RBISs in postsecondary education. This body of literature has identified methods for developing an innovation that faculty will adopt within their context. For example, Fournier-Bonilla et al. found that identifying and responding to sources of resistance to curriculum change was an important factor in sustained curriculum change [14]. Such studies point to a need to better understand faculty and thus the sources of their resistance and appropriate responses.

Moreover, Henderson and Dancy claim "the biggest barrier to improving undergraduate STEM education is that we lack knowledge about how to effectively spread the use of currently available and tested research-based instructional ideas and strategies" [15]. Their work shows that although instructors are aware of RBISs, will claim to implement these strategies in their classroom, and generally show interest in incorporating RBISs into their teaching [15], faculty are generally slow to implement and adopt these strategies [16, 17]. Put another way, faculty can be motivated to implement changes, but might not have the tools or skills needed to most effectively initiate and sustain those changes.

The most prevalent way of developing RBISs for classrooms employ a "one-size-fits-all" model, where all faculty are presumed to adopt practices in the same way. But at the same time, Hutchinson and Huberman suggest it is impossible to avoid the individualization of an instructional practice and highlight the importance of understanding individual differences and nuances across subject, course, etc. [18]. Therefore, a useful RBIS should be one that is sensitive and flexible to the needs to individual faculty members. Given that student engagement is often a core feature of these RBISs, the use of a student engagement measurement tool can help faculty assess the effectiveness of the customization of practices. Ideally, faculty can use this measurement to guide their implementations towards greater student engagement. Researchers are thus needed to play an active role in expanding the use of existing RBISs through working alongside faculty to develop conceptions of how an innovation may prove useful in their own context [19].

Work in STEM education supports user participation in the development process. For instance, Khatri and colleagues identify three key features of moving innovations towards sustained use: (1) working alongside faculty in an iterative manner of development; (2) disseminating innovations in a way that allows for feedback; and (3) providing support to those adopting innovations [20]. Additionally, Borrego, Froyd and Hall [21] suggest adoption levels will be higher in situations where clients' needs are emphasized over promotion of a specific innovation. Such findings and others suggest faculty members play key roles in developing engineering education innovations [21]. Faculty-centered development and implementation techniques can thus promote sustained use of instructional strategies.

2.2 Sensemaking

Karl E. Weick and Kathleen M. Sutcliffe present sensemaking as a means of understanding how individuals adjust to their ever-changing surroundings [13]. Organizations are the site of these authors' studies and the environment in which sensemakers are said to be situated. For this context, *organizations* are defined as the order and structure of the institutional context, from which faculty themselves negotiate particular meanings and rules for their teaching and related work [22]. The process of sensemaking is ongoing and occurring continuously; as a sensemaker experiences the current state of the world to be different than the expected state of the world, or a way in which to engage the world is not obvious they are compelled to explain their actions [13]. The propelling force towards action is the dissonance between expectation and reality, a *disruption* for the sensemaker.

Individuals in an organization are said to undergo sensemaking on behalf of the larger unit, situating individual sensemakers as both actor and storyteller of events shifting an organization [12]. For example, consider a faculty member who is beginning to wonder how use of measurement tools in her classroom can inform her teaching. She may begin by considering how SETs can inform improvement in her teaching strategies. In the past, her normal state was considering SETs as an evaluation that she reported to the department chair. Her normal is disturbed, and she begins to consider what parts of SETs can be used to change her teaching, and also begins to discuss SETs in this manner to her colleagues. In this way, she is both is undergoing sensemaking and telling others about her new perceptions. Her actions, set in the organization of the university, are representative of this unique climate.

Sensemaking relies on the premise that ''action is always just a tiny bit ahead of cognition, meaning that we act our way into belated understanding'' [12]. In other words, as sensemakers interact and engage with others in our organization, their actions are driven at first by reflex and later by reflection. To continue the example, perhaps the faculty member here reacted to the disruption with concern over new metrics of performance into a classroom. However, upon further reflection, and sensemaking, the notion of incorporating SETs seems potentially helpful. She had not thought of them in this way before, instead she just was going to turn them in and forget about them. When asked why she made such changes, the faculty member might cite her chair's questioning, her desire for improvement in her teaching, and interest in incorporating student feedback. She could only come to an understanding after having taken action; a different action would have resulted in a different cognitive understanding.

To describe the belated understanding resultant from action, Weick's sensemaking framework is broken into seven core properties: *identity, retrospection, enactment, social, ongoing, extraction of cues, and plausibility* [12]. Table 1 defines the core properties of sensemaking as they will be used in the paper, based on a summary of Weick's work [12].

Core properties describe the range of ways in which sensemakers make meaning of the action they take. Continuing the example from above, we can see that respect for authority and improvement in teaching might be part of the faculty's identity. She may have used retrospection when she selected example problems as the means of addressing students' concerns; perhaps she recalled an event where she had tried to completely restructure her course and it had failed but modifying small portions had been successful. Enactment showed up as she shaped her classroom environment, and then addressed the feedback resulting from this newly formed classroom. In her modified classroom environment, students seem to be lacking in theoretical background and it is resulting in lower test scores and poor SETs. She then makes changes based on

Table 1. Definitions of the Sensemaking Core Properties

Core Property	Definition from Literature
Identity	The utilization of relevant pieces of self, allowing one to bring to prominence an appropriate self to face the challenges of an environment.
Retrospection	The recollection and likening of past events to present circumstance. Seeing the past as casual and correlated to present outcomes and actions taken.
Enactment	The simultaneous construction and response of one to the environment. Shaping the environment to which they respond; the environment pushes back on the response of individuals.
Social	The negotiation of one's role in an environment based on the predicted, perceived, and physical response of others to their action.
Ongoing	The continuous, never ending loop of sensemaking with no beginning or end, resulting in each new situation acting as a stimulus that challenges or affects the process of making sense.
Extraction of Cues	The selection of pieces of information as the most meaningful in a given context, pointing towards a rational set of responses that give meaning to the larger whole.
Plausibility	The tendency of sensemakers to be less likely to follow a call to accuracy than a call to action that will lead more directly, quickly, or simply to a desirable outcome.

this new environment she herself formed. The discussion that the faculty began with her colleagues helps explain her own actions. Maybe in her social work spheres there is a general value on betterment of teaching, and she wishes to conform to this value. She certainly did not make the decision on how to restructure her course based on an isolated feedback, rather the thoughts on how she structured her course in the past and how she hopes for it to be structured in the future remain ongoing. She extracted cues from her SETs that focused on example problems to help make sense of her action to change that about her course. Finally, she really cannot be sure that these changes will result in higher SET scores or appease her chair, but this is deemed plausible and is therefore reason enough for her to take action even if her assumptions are inaccurate.

Though literature exists on the observable actions faculty take towards innovative pedagogies (e.g., adoption, implementation, fidelity), relatively little is known about how they explain their actions as they anticipate and make changes to their instructional practices. Being asked to think about the classroom in a new way is a disruption to normal faculty behavior, and sensemaking allows researchers to understand how faculty arrive at their new normal. Additionally, research related to changes in instructional practices demonstrate the utility in including in the development of innovations. As a result, in this study we focus on faculty sensemaking during their involvement in the development of an innovative educational tool—i.e., the ICCE survey.

3. Methods

The purpose of this study is to explore faculty perceptions surrounding the potential adoption of a research-based survey instrument (i.e., the ICCE). To that end, we asked the following research question:

How are sensemaking's core properties described by faculty participants as they interact with the ICCE survey?

This study emerged out of the need to better understand the journey faculty undergo when asked to adopt a survey tool to operationalize in-class student engagement. The introduction of faculty to the ICCE survey served as a *disruption* to the expected state of their course. In the example of a possible disruption, faculty do not normally systematically consider how students are engaged in the classroom. In this case, the *expected state* is that classroom practice does not include measurement of student engagement. Participation in the ICCE survey development asked faculty to consider student engagement systematically. The *disruption* is the invitation and opportunity to measure student engagement in classroom practice. This discontinuity required faculty to make sense of the atypical experience. The seven core sensemaking properties, as summarized from Weick's work [23], were used to interpret the experiences of faculty with the ICCE survey and to offer insight into their perceptions related to its implementation in their course.

Though adoption is the ultimate goal of the instrument development, it is important to note this study focuses on faculty sensemaking *leading up to adoption*. Given the sparse nature of research in faculty understanding of educational innovations such as the ICCE, an important first step was to explore the way faculty might ultimately interpret the use of the instrument. This was part of a larger study seeking to supply faculty with an innovative survey tool to allow them to understand better the cognitive and social engagement of their students. Though there are many different kinds and modes of engagement (e.g., cognitive, social, in-class, out-of-class), the present work is focused on cognitive engagement behaviors within classroom settings.

3.1 Engagement

Foundational to tool development is an operational definition of what engagement means in the classroom. Researchers Chi and Wylie suggest cognitive engagement can be empirically inferred based on overt behaviors [5]. As a result, they developed the ICAP framework to allow researchers to link unobservable mental states (and therefore learning processes) to observable classroom behaviors and interactions. ICAP posits four modes of cognitive engagement: Interactive, Constructive, Active, and Passive. This model also posits that higher levels of learning (or knowledge-change processes) occur with higher modes on a hierarchical scale, i.e., Interactive > Constructive > Active > Passive [5]. The link between observable and unobservable offers a potentially more objective, empirically valid measure of student cognitive engagement. To date, however, the framework has been used primarily to advance discussions of theory. Therefore, we leveraged the ICAP framework to develop a set of survey instruments to measure modes of engagement. The survey instrument (ICCE survey) was the topic of discussion between faculty and researchers in this study.

3.2 Data collection

3.2.1 Sampling

Participants were initially targeted based on the large enrollment size of their course, as well as how frequently they taught lower-division required, or capstone-required courses. Utilizing convenience sampling, the majority of faculty initially recruited were known by the research team, either by personal encounter in a professional setting or work on a prior project. Snowball sampling [24] followed in subsequent rounds of recruitment. Snowball sampling provided the research team with additional access to faculty potentially open or interested in the measurement of student cognitive engagement. Recruitment occurred over three terms (one academic year). Initial contact was made with participants via email or in-person which included a request for faculty to distribute the ICCE to their current class(es) and participate in an interview. In line with sensemaking theories which position the individual as both the author and storyteller, participants played the dual role of user (implementing the survey in their course) and developer (agreeing to an interview in which they gave feedback on the instrument and the construct it was measuring). All participants who agreed to implement the survey also participated in the interview. In total, there were 24 different faculty participants over the three terms of study. A summary of participant demographics is presented in Table 2 to provide insight into the varied nature of classrooms represented in this study.

3.2.2 Interview

Interviews were semi-structured, with structure ensuring participants had the opportunity to discuss each core property and openness allowing for deeper inquiry into themes participants identified as particularly salient. The semi-structured interview had two distinct topics of discussion. In the first portion of the interview, participants discussed the structure of their course, their journey to teaching that course, and the role of engagement in their teaching philosophy. The purpose of this phase was to gather information about the course while marking participant's *expected state* as related to measuring engagement.

After discussing engagement in general terms, the interview shifted to discuss engagement in terms of the ICCE instrument and its use in their course. That is, we sought to cause a potential *disruption* for the participant. To make this transition, the interviewer presented participants with the ICAP framework as a means of discussing engagement in the classroom. Participants were provided a brief overview of what the framework was and how it might be useful for understanding engagement in their classroom. Knowledge of the ICAP framework provided participants with a foundational understanding of how the survey was developed and allowed them to provide meaningful input and feedback.

Following the discussion of the framework, participants were shown the PDF version of the survey their students would take in Qualtrics, an online survey platform [25]. When presented with the instrument, participants were told how each mode of ICAP was addressed in four to ten questions. Questions prompted participants to discuss what stood out to them and their overall perceptions of the instrument. Participants directed their way through the survey, spending as little or as much time as they desired reading through individual questions. After participants read through the survey, the interviewer asked questions to target both positive and negative perceptions of the survey and its usefulness to them as an educator. Interviews lasted between 20–45 minutes. Table 3 provides sample interview questions for each of the core properties.

3.3 Data analysis

In this study, faculty sensemaking occurred in the context of their academic institution. As educators made choices that led to their understanding of how student engagement and its measurement impacted them, sensemaking was used to capture the change in thought patterns. The site of sensemaking observation was interactions between faculty, researchers, and the survey instrument. The seven properties of sensemaking were used to develop data collection

Table 2. Summary of demographics related to faculty participants

Classroom Type	Institution Type	Class Subject
Traditional classroom: 16 *(lecture, lab, and/or recitation)*	4-year research institution: **17**	General engineering: **8** Chemistry: **4** Biology: **4**
Flipped classroom: 8 *(non-lecture based)*	4-year teaching institution: **4**	Chemical engineering: **3** Computer science: **1** Civil engineering: **1**
	2-year teaching institution: **3**	Environmental engineering: **1** Mathematics: **1** Physics: **1**

Table 3. Sample Interview Questions and Mapping to Sensemaking Core Properties

Sensemaking Core Property	Sample Interview Question(s)
Identity *(utilization of self)*	How did you come to teach the course this survey will be used in? What impact do you see the assessment of student engagement having on you as an educator?
Retrospection *(connecting past to present)*	What was your motivation in agreeing to use the survey? Have you used an educational survey or participated in educational research before?
Enactment *(interaction with environment)*	Are there aspects of the survey that you think are more important or relevant to you/the way you teach/your course content?
Social *(interplay of self with others)*	What kind of communications have you had with coworkers or others regarding your decision to use the survey?
Ongoing *(endless loop of making sense)*	What role do you see this type of survey having in your class?
Extraction of Cues *(selection of information bits)*	What aspects of the survey stand out to you?
Plausibility *(preference of action to accuracy)*	What are you hoping to get out of implementing our survey? Do you foresee students using this survey in a way that will provide useful feedback to you?

and analysis protocols as well as guide the iterative, deductive analysis of the interviews.

All interviews were conducted by the lead author and transcribed by a third party. Transcriptions were coded using Dedoose [26]. Deductive coding was used in the first cycle of data analysis [27], with an applied codebook that used each sensemaking core property as a code. Definitions for each code were originally based in the literature and were refined in the first cycle of data analysis to present sensemaking as it was observed in participants. Table 4 provides a summary of the seven codes applied in the first cycle of data analysis. In the second cycle of data analysis, we used pattern coding to associate each of the seven sensemaking codes with positive or negative adoption potential [28]. Similarly coded excerpts, as opposed to participants, were analyzed for patterns, meaning a participant could exhibit both positive and negative adoption potential while undergoing different aspects of sensemaking.

3.4 Credibility and trustworthiness

Credibility is defined as the degree to which the findings provide an accurate representation of a phenomenon, and whether that representation is consistent with participants' experiences of it [29]. To this end, I, the lead author, worked extensively with the data to develop robust representations of participant experiences, and conducted research alongside a team of engineering education researchers who validated my methodology, results, and findings throughout the study. Faculty interviews were initially conducted with two engineering researchers. Following the interviews, researchers discussed key takeaways. Interview data were then coded in two phases. Two peer debriefing sessions [30] were held in each coding phase with researchers/

Table 4. Codebook definitions of sensemaking core properties

Core Property	Codebook Definition
Identity *(utilization of self)*	Willingness to learn about engineering education and related research; role of educator in engaging students.
Retrospection *(connecting past to present)*	Past factors influencing the usefulness and accuracy of student feedback, including word choice and response variables.
Enactment *(interaction with environment)*	Changes in instructional practices leading to changes in student perceptions; feedback loop between educators and their students.
Social *(interplay of self with others)*	Interactions with parties influential in decisions to make changes to instructional practices, particularly implementation of ICCE survey.
Ongoing *(endless loop of making sense)*	Influence of usefulness and repeatability on the meaning of surveys in the classroom.
Extraction of Cues *(selection of information bits)*	Applicability of specific questions and language to a given class context.
Plausibility *(preference of action to accuracy)*	Factors viewed as likely that lead to a given action, including assumptions about self-report, participation bias, and reliability.

coauthors who questioned methods, meanings, and interpretations until consensus was reached.

Trustworthiness is defined as the degree to which findings are represented honestly and evidence for such findings is sufficiently documented [27]. Important to this study was the way in which sensemaking's core properties honestly represented participant's perceptions of engagement and the ICCE survey. To achieve this, definitions of the core properties were reformatted and operationalized for clarity and bounded meaning. In peer debriefing sessions [30], coauthors reviewed and questioned the ways in which participant excerpts were used and explained throughout the results. Concerns were addressed and reviewed to ensure clarity and integrity of the findings.

3.5 Limitations

Several limitations should guide the interpretation of the following results. First, convenience sampling inherently biased the results by favoring a particular institution, and group within the institution. The existing relationships between the research team and participants in the present study affected the willingness and enthusiasm participants showed for implementing the ICCE in their classrooms. Second, though both traditional lecture-based and flipped classes participated in this study, the ICCE survey was designed primarily for courses with an in-class lecture component. Those with flipped classrooms were limited in the ways in which they could interpret questions based on their context. Third, participants were engineering disciplinary experts and therefore lacked in-depth knowledge of constructs such as cognitive engagement and indeed ICAP in particular. As a result, participant perceptions regarding constructs such as student engagement might be more informed by their own experiences and personal definitions than by cognitive science and related research. Lastly, the iterative nature of the survey development caused early faculty participants to encounter a different instrument than later participants. As noted, the interviews took place over three academic terms, during which improvement and refinements were made to the ICCE survey. Therefore, some later participants responded to a significantly shorter, arguably simpler diagnostic instrument. To fully understand the long-term adoption of the ICCE survey and resultant changes from its use, a longitudinal study would be beneficial.

4. Results

Results show faculty sensemaking process as related to the seven core properties by describing their perceptions of engagement and the use of the ICCE survey in their classroom. Results are presented by discussing how the seven core properties of sensemaking provide insight on faculty interactions with the instrument (their evaluation and adoption). The discussion of core properties is followed by an outlining of the most influential factors in participant adoption.

4.1 Sensemaking processes

An important aspect of this study is the development of an understanding of participant perceptions leading them towards or away from implementation of the ICCE survey; in large part because such an understanding will increase the potential for adoption of future instruments. By discussing each of the seven core sensemaking properties in turn, the following sections illustrate how participants embark on a journey of sensemaking in response to the potential adoption of the ICCE survey. We present examples relating to each property, highlighting both the range of sensemaking processes participants underwent and the salient factors influencing participant perceptions and willingness to implement the instrument.

4.1.1 Identity (utilization of self)

As noted, identity refers to the degree to which a sensemaker considers one's own preferences, approaches, experiences, etc. in light of a disturbance; they utilize a version of themselves that allows them to take action in their environment. Here, participants focused on their involvement in STEM education and their research background when discussing their identity as it related to engagement. They frequently referenced their previous research, STEM education research or otherwise, when discussing their thoughts on the ICCE survey. For participants with a STEM education research background, adoption of the instrument was seemingly a natural continuation of either contribution to the field or personal development as an educator. For those participants who did not have a background in education research, a general interest in education research was seen:

> Avery: "I have *almost no experience with educational surveys and engineering education*. This is my third year to teach engineering. I've done some reading, and *I'm trying to learn about that field*, but it isn't my field."

Motivation to begin or continue to understand the field of STEM education and the best practices associated with it was driven by participant identity as a teacher of students. Participants felt that their work identity included the engagement of students in the classroom, and a willingness to learn what engagement might look like in their specific classroom. Riley stated "*I just see it as part of my job*" when discussing embracing new pedagogies and surveying for student feedback.

4.1.2 Retrospection (connecting past to present)

Retrospection is defined in terms of the perceived connection between past events and their influence over current circumstances. In this study, participants expressed their recollection of past questions posed to students and past usage of class surveys. Participants tended to recall events that illuminated how students made sense of words, phrases, or ideas. This retrospective process influenced how participants believed students would interpret, and therefore respond, to different ICCE survey items. Retrospection often followed an extraction of a cue, bringing to mind a story or instance likened to the ICCE survey. As seen below, stories recalled often centered around mistakes or misinterpretations participants hoped to avoid when adopting the ICCE survey in their classroom:

> Kerry: "It's a really minor thing, but the instructions, the wording... I don't know how to say it better, but I know that particularly students learning English as they go have a hard time understanding that . . . *I just thought of that because the final I just gave had some wording like that, and there was a line of people like, 'What does this mean?'*"

Kerry likened the language used in the survey to a past event in which many of his students lacked comprehension due to language barriers. Of particular concern to Kerry was the potential limitation to those learning English. Sensemaking of the ICCE survey was influenced by this retrospective event, as concerns from the past incident were brought into the new context. Past concerns were brought to light through retrospection associated not just with wording used in the ICCE survey, but also usage of surveys as a whole:

> Peyton: "My understanding is that typically when we do these surveys *the students that we really most want to hear from are the ones that we very rarely do*, because they're often the ones that opt out on these surveys. *That's certainly been my experience as well.*"

In Peyton's mind, the results of the survey would come from the students from whom he does not need feedback. Concerns around survey usage, particularly associated with the constituent of students responding, was commonly observed, yet participants concluded that on the whole students would use the survey in a way that would be useful to them.

4.1.3 Enactment (interaction with environment)

Sensemaking through enactment occurred as participants perceived students both as the environment and the stimulus for change. Participants sought to understand their class as a means of change. Change was often targeted at improvement, be it through the incorporation of new educational strategies or removal of past unsuccessful ones:

> Jaime: "*I want to know what works*. What *particular* teaching practices work. *I know what the research says works*, but I really get the impression that every class is its own personality and what works in one classroom may not work well in another. So I'd really like to know *what bits of what I'm doing are working and what bits I really need to focus on fixing. That's what interests me about doing this.*"

Jaime spoke of a theme common among many participants—wanting to know what works. As Jaime enacted different educational strategies in the classroom environment, the perceived response of the class played a role in future decisions, including the decision to adopt the ICCE survey. Participants were motivated to get this feedback to enable change, as the commonly held belief that their knowledge of students' perception was limited. This limitation acted as stimuli for participants to adopt the ICCE survey as a means of response.

4.1.4 Social (interplay of self with others)

Sensemaking theory suggests that no decision is made in isolation, and participant perceptions echoed such claims surrounding the adoption of the ICCE survey. For participants here, social sensemaking took the form of respected education researchers. For some, that authority of the researcher was the primary point of sensemaking:

> Blair: [Research team member] said, " 'Hey can you do this?' Without knowing too much about it, I looked through the questions, but I see that you guys just need volunteers who are willing to do this. *I'll pretty much just play along*. If you give me a survey to send out, I'll send it out but that *I don't really have any purpose or a goal myself, necessarily*."

Social sensemaking allowed the instrument to have meaning in Blair's context, despite his claim to not have any "*purpose or goal*" himself.

Interaction with educational researchers was the primary point of social sensemaking; nearly all participants indicated they had not spoken with coworkers regarding their decision to adopt the ICCE survey. Notable exceptions included participants who co-taught or taught the same course in the same term.

4.1.5 Ongoing (endless loop of making sense)

Sensemaking is a process that has no beginning and no end, meaning sensemaking that occurred long before participants saw the ICCE survey influenced their perceptions of it, and were influenced by the future they projected surrounding its adoption. For example, the ways in which participants collected student feedback in the past influenced their perception of the ICCE survey, in addition to the way they predicted adopting the ICCE survey would influence their teaching in the future. In this way, the ongoing nature of sensemaking allowed participants to make steps towards adoption without extensive knowledge about the ICCE survey or its use in their classroom.

Of consistent importance to participants was the ability to create a continual feedback loop between the ever-changing classroom environment they create and their students:

> Kerry: "Yeah, when it's good, when you feel confident in it, *I would like to use it at least every time I change something*. Which, judging by the past will be every term. Then maybe if I could even more a shorter version, just to get quick feedback . . . *I'm constantly trying to assess what they're thinking, if they're thinking about the right things*. I don't have a lot of tools to do that so this would tell me what type of thinking they're doing, *which would really help."*

Kerry's interest was seen as both pending and decided, based on not only the survey's effectiveness ("*when it's good, when you feel confident in it*"), but also its ability to provide insight into Kerry's understanding of what students are thinking ("*I'm constantly trying to assess what they're thinking*"). Collectively, participants spoke of lacking tools to assist them in understanding student perspective.

4.1.6 Extraction of Cues (selection of information bits)

When looking at the survey questions on the ICCE survey, participants extracted cues that informed their understanding of the survey as a whole. A singular or few extracted cues were enough to inform participants whether the ICCE survey was relevant to their classroom. The cues extracted frequently centered around language participants believed would be unclear to their students. Of additional concern was the use of language that participants believed led to content not present in their class:

> Peyton: "*When I hear example problems I think that's a math problem*. There's variables. There's addition. *There's never going to be that in my class*, so what do we mean by example problems when you ask these questions?"

Language that participants believed could not relate to their course created negative perceptions of the survey, as they believed certain questions prevented students from providing a holistically accurate picture of engagement in the course.

A similar phenomenon was observed when participants believed their course structure diverged from the course structure implicitly suggested in the survey: For example, when students were asked about writing notes in class, suggesting a course structure that included a time to take notes, some faculty participants stated that they do not do notes in the classroom. Yet nearly universally, participants with more traditional classrooms saw notes as a way they could gain useful feedback from students through use of the ICCE survey.

4.1.7 Plausibility (preference of action to accuracy)

As the outcome of implementing the ICCE survey remained unknown by participants, they took action in implementing the survey they saw as plausibly useful (with limited evidence on their assumption's accuracy). That is to say, sensemakers are seen to take action on the possibility that the action will prove favorable, even if their possibility cannot be proved to be accurate. Plausibility here took the form of assuming that students would respond with honest, useful feedback to the ICCE survey. Participants willingly admitted that honesty was not guaranteed, yet they still displayed excitement over the outcome of the survey:

> Carey: "I feel like I get a range of responses where I can see the students . . . generally it seems like they're not just clicking to click, I guess. *So I think they would use it in a way that would be good data for us*."

Carey's plausible belief built her confidence that the data gained from ICCE survey would prove useful, which prompted her action to implement and look to the survey as a source of truth about her students. Not all plausibility led to belief in the results of the ICCE survey. Some participants used plausibility as a means to discount the results prior to students ever engaging with the instrument:

> Avery: "I hope enough of them take it that it's useful. *If there's only like twenty, then you can assume that 15% of those are the top people that do everything* . . . Go getters. In some ways, it's better to have the feedback spread among the class. I'm hoping 85% or more, but we'll see."

Though this may not be an accurate statement, Avery's action (filtering responses through the lens of the top 15% of the class) was based on her plausible assumption.

4.2 Summary of results

Participants underwent sensemaking of the ICCE survey and the idea of a tool informing them of in-class student engagement. While all seven sensemaking core properties informed overall sensemaking, they played different roles. That is to say, though participants will have described their sensemaking process in terms of all or many core properties, they likely relied most heavily on one or two to explain their actions. Participants who relied heavily on social, identity, enactment, and ongoing

Table 5. Themes of each core property and their relationship to adoption potential

Core Property	Examples from Data	Adoption Potential
Identity ***(utilization of self)***	• Faculty are willing to learn about engineering education and related research • Faculty will seek to engage their students	*Positive*
Retrospection ***(connecting past to present)***	• Word choice will influence student interpretation • Feedback provided by students will be limited	*Negative*
Enactment ***(interaction with environment)***	• Survey will provide a feedback loop between changes to instructional practices and student perceptions	*Positive*
Social ***(interplay of self with others)***	• Interactions with researchers are useful for faculty making meaning of the survey	*Positive*
Ongoing ***(endless loop of making sense)***	• Usefulness of the survey will be determined after its use • Repeated use of the survey will provide useful feedback on changes to instructional practices	*Positive*
Extraction of Cues ***(selection of information bits)***	• Survey language used is not applicable to every classroom context • Questions on notetaking will provide useful feedback, if interpreted correctly by students	*Negative*
Plausibility ***(preference of action to accuracy)***	• Students will report honestly • Survey will reach only a subset of students	*Negative*

sensemaking to explain their action response to the ICCE survey frequently were explaining a process that culminated in adoption. Conversely, participants who relied heavily on retrospection, extraction of cues and plausibility over accuracy in the end did not undergo sensemaking that led them towards adoption. For example, by understanding how Peyton was influenced by her extraction of cues related to the language of *example problem* not relating to her students, negative adoption potential was seen. In the case of Peyton, she may have had some positive perception of the ICCE survey (i.e. when considering the part of her identity that sought to engage students) but did not rely on such core properties when explaining her action. Therefore, reliance on a particular core property of sensemaking was seen to be associated with a particular action. A summary of the core properties, the emergent themes presented in the results, and their relation to adoption potential are located in Table 5. The following discussion uses the sensemaking framework to explain poignant examples or patterns related to adoption and how the ICCE survey might be modified to better meet the needs of faculty.

5. Discussion

In studying how these sensemaking core properties were described by participants as they interacted with the ICCE survey, the examples were similar to those found in the literature. Though not discussed in terms of sensemaking, the participant embodiment of the core properties was consistent with previous work on change in instructional practices. For example, Hutchinson and Huberman suggest it is impossible to avoid the individualization of an instructional practice [18]. Participants in this study were concerned with individualization of the ICCE survey to meet their needs (e.g., faculty in a flipped classroom concerned over questions related to notetaking). They relied on extracted cues to describe the ways in which a generalized survey limited the relevance or applicability of the results. Indeed, we believe the likelihood of long-term survey adoption would decrease without individualization based on these findings.

Furthermore, pitfalls observed in this study with the ICCE survey were similar to faculty perceptions surrounding the use of student evaluations of teaching (SETs). For SETs, these pitfalls include a general concern over reliability and validity [31] and a lack of consensus as to the meaning of results [32, 33]. Additionally, SET literature suggests faculty will be hesitant to make use of student feedback if they do not perceive the instrument as a valid measurement tool, in other words, as *useful* [34] and will be prone to misinterpret the results without guidance from instrument developers [35]. In this study, the similarity of the concerns held by faculty may have been in part due to retrospection. Faculty readily compared and contrasted the ICCE survey to SETs, with similarities including students "judging" the effectiveness of teaching and differences in the potential for feedback related specifically to engagement. As a result, new surveys, including the ICCE, must contend with the limitations encountered by faculty in previous soliciting of student feedback. In support of this discussion, the following section will focus on how the sensemaking framework core properties and their relevant examples are related to adoption potential.

5.1 Discussion of adoption potential

The majority of the participants in this study chose to implement the ICCE survey in the course they were teaching during the term they were interviewed. These participants often used similar sensemaking pathways (identity, enactment, social, and ongoing; see Table 4) in their understanding of engagement and the ICCE survey. Even though the data suggests that participants valued in-class engagement, there remains a range of exposure and experience with educational research and emerging RBISs in STEM faculty, which should be addressed. Some survey implementers had classrooms in which an identity-value of engagement led them to make regular changes to their courses, while others simply sought initial feedback. Both needs led participants to adopt the ICCE survey, yet sustained adoption would likely be influenced by the meaningfulness of the results. (Feedback from our results points to how participants used enactment to make sense of the ICCE survey: participants were looking to adopt an instrument that would supply them with feedback, allow them to make changes, then use the instrument again to measure these changes. Participants generally perceived the ICCE survey to be such an instrument, aiding in its adoptability.)

Influenced by the social property of sensemaking, it is worth noting that adopters of the ICCE survey in many cases were motivated simply because they were asked by a researcher. The nature and degree of the relationship between researcher and adopter was varied, with most being little more than acquaintances. The association of a name and researcher with an innovation was a motivating factor in its use. Participants made sense of contributing to the research community at large and interacting with engineering education, and followed by making sense of the ICCE survey alongside researchers. Participants perceived that effective instruments came from effective researchers and research communities. Participants cared about the "big idea" and were willing to trust the researchers' means to explore an idea like engagement. This necessarily poses a concern for sustained adoption, as eventually social interactions with researchers will decrease. The goal of the larger project is to develop a survey that is self-sustaining (faculty are motivated enough by benefits that they will continue adoption on their own accord) or valued among enough of a community that faculty will continue to use social sensemaking as a pathway to adoption.

Throughout the present research, it became clear that in-class engagement was an ongoing concern for participants—they were ready for a tool that allowed them to measure their students' in-class engagement. This aided in the successful adoption of the ICCE survey. For the implementation of RBISs lacking in an established foundation among faculty, the findings here suggest a key first step is convincing faculty to incorporate the desirable value into their identity. Ongoing sensemaking allows faculty to bridge the gap between what they have valued in the past and what perceive themselves valuing in the future.

5.2 Discussion of adoption limitations

Conversely, participants who focused on sensemaking related to retrospection, extraction of cues, and plausibility expressed limited interest in long-term adoption. Retrospection brought to participant's mind the failings of previous surveys and were applied to the ICCE survey. To mitigate these concerns, evidence would likely be needed to convince faculty that the ICCE survey would perform differently. Participants were particularly concerned with the applicability of the survey to their class. A challenge is posed in a climate in which STEM classes can vary widely in structure. Flipped classrooms, for example, intentionally engage students differently than traditional lecture-based class. The ICCE survey would need to be modified to make it useful to both classroom types, perhaps separately.

Participants who extracted cues related to language they believed did not apply to their course were resistant to adopt the survey. Even if the majority of survey content was applicable, participants could be dissuaded by a single word usage. As the ICCE survey seeks to measure in engagement in various STEM classes, it is important to use generalized language that is widely applicable or develop a set of questions unique to different disciplines. Participants were concerned with not only how students might interpret specific words, but generally the accuracy with which students can report on things such as their in-class engagement. Regardless of how accurate self-report is, some faculty are likely to hold to their beliefs as the highest truth in the classroom simply because it is both plausible and efficient. It must be made plausible to such faculty that students hold additional truth worth accessing, and that it is accessible through a certain tool.

6. Conclusions and future work

In this study, we used the sensemaking framework to describe participant perspectives as they moved towards reform centered on cognitive engagement. As reform efforts continue, it is important to consider these findings in light of future activities, instruments, and RBISs. Faculty must be sought after in their own contexts, so as to offer meaningful feedback during development of measurement tools for their classrooms. Researchers developing instruments should carefully consider their language use and the resistance such language may generate among faculty; the flexibility of the survey used in this research resulted in positive perceptions of its adoption.

When interacting with potential faculty adopters, researchers might try to trigger sensemaking properties of identify, enactment, social, and ongoing, as this was found to relate positively with adoption potential. One way in which this could be accomplished is through recruitment materials or initial introduction to an innovation. Alternatively, researchers should try to mitigate the expressions of their innovation that can trigger retrospection, extraction of cues, and plausibility. Perhaps this could be accomplished by preparing to mitigate faculty concerns, for example explaining how a new measurement tool is different than the SETs and will not recreate the poor experiences highlighted through retrospection. It is important to be aware and seek to meet the individualized needs of faculty, lest they see the instrument as research with little benefit to them.

While participants clearly indicated their desire for a flexible, customizable tool, tension exists between their desire and the expertise of researchers. In our study, the researchers had a background in engineering education and experience with theories of learning, such as ICAP, which allowed us to develop a tool to measure engagement. Faculty, on the other hand, have a perception of engagement that has grown out of their teaching experience. Engineering education researchers seek to provide faculty with valid, reliable instrumentation to measure engagement while faculty seek to modify it to make sense in their own context. This work is part of establishing an instrument development process that allows for flexibility within reliability. The greater knowledge we have of participant perceptions has continued to inform the development of our instrument and serves as a model for other engineering educators seeking to develop such instruments. Our aim is to have contributed positively to the innovative development model movement that will allow for the creation of useful tools to understand better RBISs in the classroom, resulting in greater uptake of RBISs by educators.

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Allyson Barlow is a graduate student studying Civil Engineering and conducting Engineering Education research at Oregon State University. Her research interests include classroom engagement, instructional change, and survey development.

Ben Lutz, PhD a Postdoctoral Scholar in Engineering Education at Oregon State University. His research interests include innovative pedagogies in engineering design, conceptual change and development, school-to-work transitions for new engineers, and efforts for inclusion and diversity within engineering. His current work explores how students describe their own learning in engineering design and how that learning supports transfer of learning from school into professional practice as well as exploring students' conceptions of diversity and its importance within engineering fields.

Natasha Perova-Mello, PhD is a Postdoctoral Scholar in Engineering Education at Oregon State University. Her research interests include conceptual change and situated cognition.

Kathleen Quardokus Fisher, PhD is an assistant professor at Florida International University in the Department of Earth and Environment and the STEM Transformation Institute. Her research interests include discipline-based education research in atmospheric science, instructional change in higher education, and diversity, equity and inclusion in the geosciences.

Shane Brown, PhD is an associate professor in the School of Civil and Construction Engineering at Oregon State University. His research interests include studies of engineering practice within theories of situated cognition and studies of students and engineers understanding of engineering concepts and conceptual change. He is a recipient of the NSF CAREER Award and numerous teaching, research, and service awards. Dr. Brown earned his BS and PhD in Civil Engineering from Oregon State University.