Using SenseMaker® to examine student experiences in engineering: A discussion of the affordances and limitations of this novel research approach

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Introduction

In 2017, the National Science Foundation (NSF) organized a workshop in Washington D.C. to introduce a new methodology, SenseMaker®, to the engineering education research community. This paper describes the development and implementation of a SenseMaker study, "The Engineering Experience Project," at the University of Georgia (UGA).

Through sharing our experiences with using this novel approach, the purpose of this paper is to start a conversation[1] about the affordances and limitations of using SenseMaker to investigate and transform cultures and practices of engineering education. To this end, we hope readers will finish this paper with a working understanding of what SenseMaker is, what is involved in designing and conducting a SenseMaker study, what the results look like, how this approach has been used in the past, and questions we are currently reflecting on as we plan our next round of data collection.

Recognizing the limitations of a conference paper, where appropriate we direct readers to additional sources that describe or showcase relevant aspects of SenseMaker. Finally, it is important to point out that this paper and, indeed, the entire development and implementation of the SenseMaker project at UGA, is the result of a collaborative effort between students and faculty members. This collaborative and participatory process is an inherent feature of SenseMaker, and one that, we believe, justifies our efforts to make sense of this dramatically different way of investigating, and potentially transforming, systems of engineering education.

This paper is organized as follows. In the first two sections, we attempt to provide readers with an overview of what SenseMaker is, how much it costs, what collected data look like, and what can be done with findings from a SenseMaker study. Next, we unpack the theoretical underpinnings of this approach, specifically with respect to narrative, culture, complex systems theory, and participatory action research (PAR). Then, we briefly describe three prior applications of SenseMaker to settings outside of higher education. We also reference one example of where SenseMaker has been used within higher education. Lastly, we discuss what we view as the three most promising affordances and three most significant limitations of this approach. We conclude by describing the next steps in our project.

As part of the review process for this paper, we were asked why we decided to submit this work to the Liberal Education/ Engineering and Society (LEES) Division of ASEE. According to the LEES website, the "division provides a vital forum for those concerned with integrating the humanities and social sciences into engineering education via methods, courses, and curricular designs that emphasize the connectedness between the technical and non-technical dimensions of engineering learning and work" [1]. To our minds, SenseMaker is a method that works to these ends. It is an approach that provides a way for actors in the social system of engineering

[1] We note that, at the time of writing, a search of the ASEE PEER document repository for the term "SenseMaker" yielded zero exact matches.

education to make sense of their experiences and decide, for themselves and in collaboration with others, how to nudge the system closer toward a state that recognizes the interconnectedness of our experiences and fundamentally human nature of our professional development.

What is SenseMaker? And how much does it cost?

The question, "what is SenseMaker?", is a difficult one to answer. To our minds, one reason for this difficulty is because the nature of SenseMaker reflects the systems it is designed to examine and change. That is to say, SenseMaker is a complex and multi-faceted approach that is designed to "probe" [2; i.e., find out about] and "nudge" (ibid, p. 1; i.e., change) complex, social systems.

At the simplest level, SenseMaker is an *online data collection and analysis platform*. Researchers, in our case a core team of one faculty member and five undergraduate students, work with the company that developed and manages SenseMaker (Cognitive Edge: https://cognitive-edge.com/sensemaker/) to design an online survey that can be sent out to actors in the system of interest. In our study, we focused on undergraduate students across our eight undergraduate degree programs in our College of Engineering. Typically, however, all actors in a system are surveyed in order to build a complete picture of the system. In our case, that would mean we would survey students, faculty members, administrators, staff etc. Because we are still learning how to use SenseMaker, we started with undergraduate students only. We do have plans, however, to expand our work to include other actors in future implementations.

Before getting into a more detailed description of SenseMaker, we would like to directly address "the elephant in the room," that is, the cost of using this approach. As one abstract reviewer for this paper observed, "I don't really understand how you would use SenseMaker, but I am intrigued to learn more. Also, the utility of SenseMaker must justify its cost."

According to Cognitive Edge, the cost of using SenseMaker is $10,000 per year per institution. The "per institution" part of this cost means that one institution might have several projects running at the same time. This service fee covers the cost of using the online data collection and analysis platform. Consultant costs, which may be required for more sophisticated data analysis, come on top of this. We note that UGA did not pay this fee for the project we describe in this paper. Our work up until this point has been covered by an umbrella license that was set up after the 2017 NSF-supported workshop in Washington D.C. As we consider continuing our work into the future and expanding our focus to include other actors in the system, we are pursuing extramural funding to cover the annual service fee. We feel that it is important to describe the fee-for-service nature of SenseMaker up front in this paper so that readers can have this in mind and consider how "the utility of SenseMaker" may, or may not, "justify its cost."

A methodological approach designed to investigate ("probe") and change ("nudge") complex, social systems

According to Van der Merwe, et al. [2], conducting a SenseMaker study involves the four iterative steps illustrated in Figure 1.

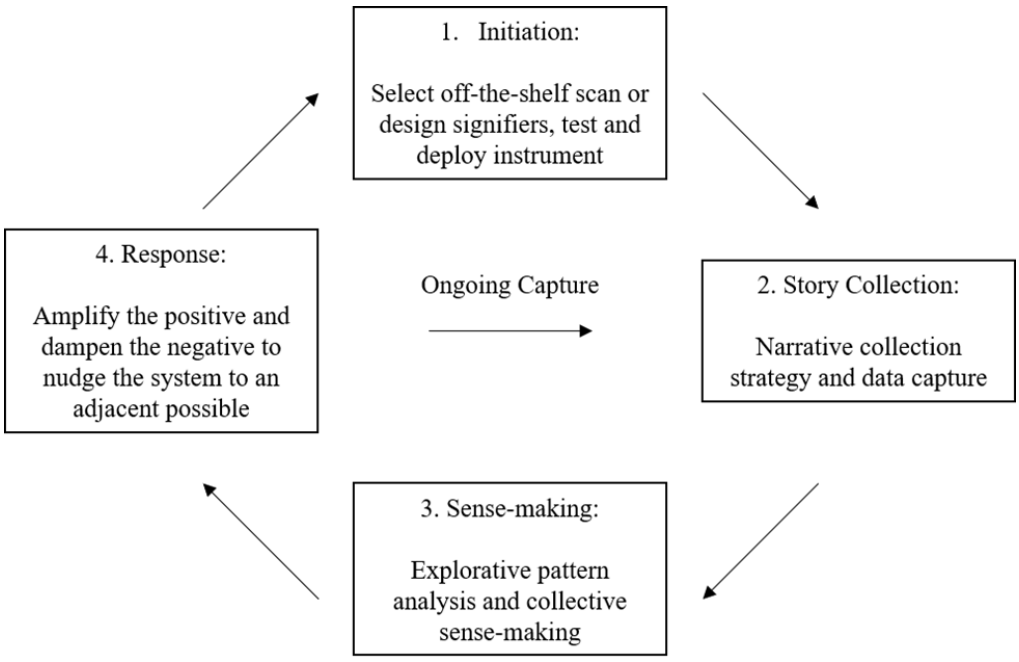

Figure 1. Adapted from [2]: "SenseMaker involves four iterative steps to: (1) design and set up the instrument; (2) probe a social context for narratives using distributed ethnography; (3) make sense of patterns across the narratives; and (4) respond based on the insights and adaptively nudge the system towards more desirable futures."

We apply these steps to our project in Table 1.

Table 1. Application of the four iterative steps in a SenseMaker study to "The Engineering Experience Project" at UGA

Step	**Application to "The Engineering Experience Project" at UGA**
1. Initiation	We developed our survey (i.e., signifiers) based on the concept of thriving [3, 4]. We note that developing our own survey instead of selecting an "off-the-shelf" instrument was a very challenging endeavor that took us 2-years to complete. Designing the survey was as much an art as it was a science (for more information see [5]). We tested our instrument in a research group (n=8; 2 faculty members; 1 Masters student; 5 undergraduate research assistants) and then piloted the survey with n=10 undergraduate engineering students.
2. Story collection	We launched our survey from 19 November to 17 December in 2019. We emailed the survey link to approximately 2,290 undergraduate students in our College of Engineering. We sent three follow-up emails, posted flyers around the main instructional building, and advertised the survey in several classes. We received 19 responses.
3. Sense-making	We are currently in the process of writing up a report of the findings, which we plan to send to all undergraduate students in our college.
4. Response	After we send out this report, we will invite all undergraduate students to a

	workshop in which we intend to collaboratively identify areas to "amplify" and areas to "dampen" to take advantage of "adjacent possibles" in the system [2].
Ongoing capture	We intend to capture another round of micro-narratives in March 2020.

From a methodological perspective, SenseMaker might be described as a *participatory, mixed methods* approach that enables the capture of hundreds to potentially thousands of *micro-narratives*. We will unpack each of these features of SenseMaker in the following paragraphs, beginning with an example of a micro-narrative.

In our study, we collected micro-narratives from undergraduate students using the following prompt:

> "Imagine you are meeting a friend for lunch. Tell them about something you have experienced recently as an engineering student at UGA."

We have described our process for developing this prompt elsewhere [5]. It is important to note that micro-narratives collected as part of SenseMaker projects can be gathered in other ways, too, such as continuous collection through journaling, where participants are prompted to tell stories on a regular basis, e.g., daily, weekly, or monthly, or working with story collectors or "citizen journalists." For example, in a study conducted in South Wales that aimed to "discover what is going well and what can be improved in different communities … [to] ensure resources are allocated where they are needed most" [6; for more information see: https://valleysstories.com/en/], citizen journalists interviewed local residents and collected 345 stories.

Micro-narratives can vary in length. In our project, they ranged from 40 to 200 words (+/- one standard deviation). Two example micro-narratives from our study are provided below to illustrate the nature of the qualitative data that are collected by SenseMaker.

> Example 1: Manufacturing Project[2]
>
> Recently, I had a project in my manufacturing class where we had to choose a manufacturing method and replicate it outside of class. My group chose thermoforming and we used the resources available to use in the FabLab to manufacture our entire project. It was super cool being able to build our own entire rig and then seeing it work perfectly.
>
> Example 2: Confusion and Disappointment
>
> My week starts off in Electronics I. I find myself increasingly bored and confused by lectures that seem of no value to my engineering education. We learn to derive formulas with no practical application from a professor who holds little care for his position. But hey! At least we can memorize the useless information for an easy test grade! And, at

[2] After telling their story, participants are prompted to give their story a title.

> least the labs are easy kits we could all buy from Amazon! I then continue to a programming class that consists of mindless mumbling and confusion. My programming knowledge in programs that are outdated in the modern field will be amazingly lacking! After classes, I enjoy chatting with friends about how their professors in classes such as circuits and sensors set them up for failure and confess to not knowing how to even lecture the information. I truly am enjoying a learning environment of dissatisfaction and half-hearted attempts to prepare students!

While we recognize the distinct contrast between these two stories, and their potential implications for teaching and learning at our institution, we ask readers to refrain from reflecting too much on them at this point, or "analyzing" them as one might approach a more traditional qualitative data analysis. For it is here that the mixed methods and participatory aspects of SenseMaker come into play. According to the creator of SenseMaker, David Snowden, one of the three basic elements of SenseMaker is the ability for participants to "self-interpret their own stories into a quantitative framework" [7]. That is to say, instead of researchers interpreting the qualitative data, participants are given the power to *make sense of their own experiences*. As described by Van der Merwe, et al. [2], "SenseMaker is a form of distributed ethnography, as it transfers the onus of interpretation of narratives from the researcher to participants." We note that Snowden describes the other two basic elements of SenseMaker as: the ability to capture observational narrative, through the methods we have described above (see also step 2 in Figure 1), and the ability to represent data in ways that show clusters of stronger and weaker perspectives and outliers of people who are thinking differently (see step 3 in Figure 1), which we will discuss later.

In SenseMaker projects, the quantitative framework that Snowden describes is referred to as a "signification framework," which includes four different types of questions: triads, dyads, stones, and multiple-choice questions (see step 1 in Figure 1 and Table 1). We provide a copy of the signification framework we developed and used in our study in Appendix A. In this paper, in which our goal is to provide an introduction to SenseMaker, we will only discuss the triads, an example of which is given in Figure 1. For more information on triads, dyads, stones, and multiple-choice questions in SenseMaker studies, we direct readers to [2].

Figure 2. An example triad from our SenseMaker project. This triad was designed to probe the concept of accountability, which is one of nine aspects of thriving described by [4].

In the online survey, participants are instructed to interpret their own stories using the triads as follows:

> Please click and drag the ball to the spot on each triangle which best reflects your opinion.
>
> You could choose one specific corner if that fits best, or between two corners, or in the middle if it is a bit of all three.

For example, the author of the first example micro-narrative above (Manufacturing Project) might decide that their story was primarily about opportunity, perhaps with a little struggle. The author of the second story (Confusion and Disappointment), however, might place their ball closer to the struggle corner, perhaps with some conflict. It is important to note here that it does not matter how the respondents interpret the concepts on the triangle. For example, the first student might interpret struggle as a healthy part of learning, while the second student might interpret struggle as struggling to see the point of what they are doing. What does matter is that the respondents "self-signify," that is, make sense of, their own stories in the way that they see fit. We note that where these two respondents actually did place their ball on this triad is included in Figure 3.

The results of a SenseMaker project comprise various visualizations of participants' responses to the questions in the signification framework. Figure 3 shows the simplest of these visualizations, which comprise our participant responses (n=19) to the triad illustrated in Figure 2. Each dot represents one micro-narrative. Figure 3 also uses color as a "filter" to illustrate additional data, in this case, participant responses to one of the multiple-choice questions, "Are you a transfer

student?" The blue dots represent non-transfer student responses, while the green dots represent transfer student responses. Looking at Figure 3, we can see that no transfer students self-interpreted their story as aligning with the opportunity corner of the triangle, while there is a cluster of transfer student narratives near the struggle corner of the triangle. Figure 3 also shows where the students who told the two micro-narratives included above interpreted their stories on this triad.

In the SenseMaker analyst software, the original micro-narratives can be accessed by selecting either a single or a group of dots. The text of the relevant micro-narratives is then shown beside the triad. This functionality enables researchers and, most importantly, participants, to explore the system of interest and identify patterns in the data.

There are many patterns that can be identified across the multiple visualization outputs that SenseMaker can generate (for more information we direct readers to [2 pp 7-8, 11]. Arguably the most powerful pattern, however, is the idea of identifying areas that indicate existing potential in the system (see "adjacent possible[s]" in step 4 in Figure 1) that could be leveraged to "create more stories like this and fewer stories like that" [8]. As stated by the developers of SenseMaker [8]:

> "[SenseMaker] enables action. Instead of asking, 'How do we create a culture of X?' we ask 'How do we create more stories like this and fewer stories like that?' Then as actions are initiated we see the impact in real time."

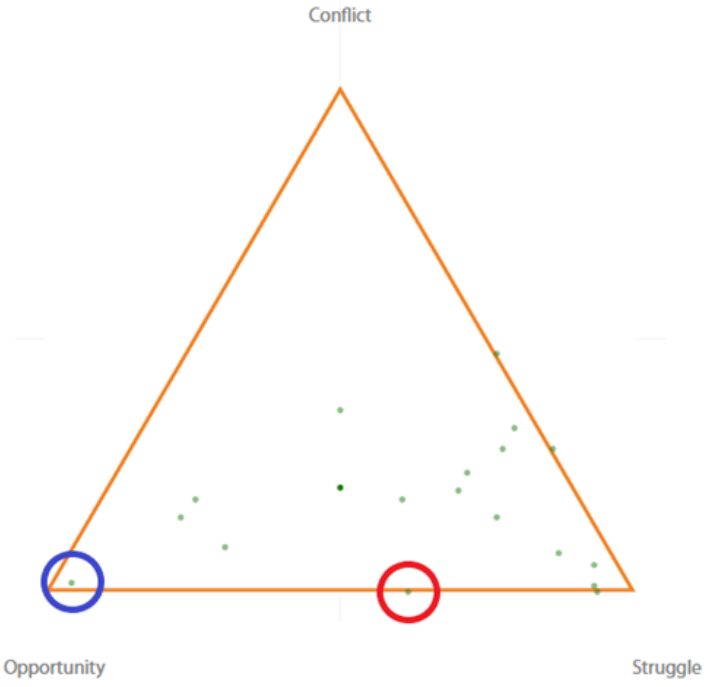

Figure 3. Participant responses to the conflict, opportunity, struggle triad, filtered by transfer student status. The blue and red circles denote the locations of example micro-narratives 1 and 2 respectively.

Looking at Figure 3, there might be an interest in reviewing the four dots that are closest to the opportunity corner of the triangle and seeing what changes could be made to our undergraduate programs to create more stories of opportunity and fewer stories of struggle. Such an approach points to the full participatory nature of undertaking a SenseMaker project, that is, to commit to working with participants in the system of interest to nudge the system in directions that leverage existing potential/ adjacent possibles in the system. Cognitive Edge has developed detailed methods to ideate, implement, and evaluate such initiatives. A detailed discussion of these processes, however, is beyond the scope of this paper, and the scope of our experience.

The theoretical basis of SenseMaker

Above we attempted to provide an accessible and necessarily brief overview of what a SenseMaker study might look like and contribute to engineering education. Before discussing prior applications of SenseMaker, we would like to circle back to the theoretical frameworks that underpin this approach. Doing so is important because some of these frameworks connect to ongoing conversations in the field of engineering education research and, therefore, may provide anchor points for readers.

Narrative and culture

According to a recent publication written by a diverse team of complexity scientists and some of the creators of SenseMaker, narratives and culture interact in the following ways:

> "People make sense of the world and give meaning to life through the construction of narratives [9-12]. How people make sense of the world is reflected in their everyday micro-narratives, the anecdotes or "small stories" people tell in social interactions. Narratives are, therefore, particularly useful for exploring social patterns of cognition [13]. Social knowledge extracted from daily rhetoric can point to what informs decisions, actions, interests, and principles and, thus, may be useful for discovering what is considered public truth and preferable behavior [10]. Micro-narratives contribute more to participative modes of sensemaking than "big stories" do [14]. Furthermore, these fragments collectively disclose identities, motivations, and attitudes [11, 15]. Sensemaking, narrative, and culture are, therefore, interwoven and give feedback to one another in complex ways." [2]

For another description of the role that narratives play in co-constructing culture, we direct readers to the YouTube video available at https://www.youtube.com/watch?v=SkRe7Xg7pk4.

The connection between narrative and culture is well recognized in engineering education. At the time of writing this paper, a search for the terms "narrative and culture" in the ASEE PEER document repository yielded 964 conference papers. In engineering education, researchers are drawn to narrative because of the ability for stories to provide insight into student [16-18] or faculty [19-21] experiences [22, 23]. As stated by Case and Light [22], "Narrative methodology focuses on collecting and analyzing . . . stories in order to understand human experience. In the context of engineering education, narrative methodology can help us understand how students

experience their education contexts." Narrative studies of underrepresented students [24-33] are becoming an increasingly popular way to investigate the experiences of groups of students that are too small to study using quantitative methods, what Slaton and Pawley [34] have described as the "small N." These studies provide rich and compelling descriptions of the challenges that are faced by these populations. Some of these studies connect minoritized experiences to features of engineering education cultures and institutional structures [25, 30, 32, 33].

The main affordance of narrative research, however, that is, its ability to uncover rich descriptions of lived experience, is also the main limitation of this research approach. A single interview transcript may be 20 to 50 pages or more and require hours of qualitative data analysis. This limitation makes traditional approaches to narrative analysis inherently unsuitable for capturing large numbers of stories in real-time, and examining changes across a system over time. SenseMaker offers a way to overcome this limitation through "link[ing] qualitative and quantitative data that can be assessed in parallel" [2].

Complex systems theory

According to Van der Merwe, et al. [2]:

> "The patterns that emerge in the narratives, heuristics, and memes of individuals, groups, or organizations are avenues for systemic meaning-making that enable researchers and decision-makers to explore the complex dynamics of social systems [35-37]. Reductionist approaches to analyze social complexity [like traditional narrative analysis] are limited in the explanations they can offer [38-41], as they ignore key dynamics and features of complex adaptive systems [42]."

There is a growing interest in using complex systems theory to conceptualize and investigate the system of engineering education. The National Science Foundation (NSF), for example, has repeatedly called for research that "recognize[s] that STEM higher education is a complex system" [43]. To date, however, the majority of complex systems-based research efforts in the field remain at the conceptual level [e.g., 44, 45, 46]. Some exceptions are the practical application of complex systems thinking to interdisciplinary faculty collaborations [47] and faculty development/ institutional change efforts [48, 49]. Another exception is the recent surge in interest in using social network analysis (SNA) to investigate the diffusion of evidence-based teaching practices in STEM higher education settings [50-53]. It is worthwhile noting, however, that while mixed methods SNA studies are increasingly recognized for their value [54], these approaches are not yet capable of linking quantitative and qualitative data in parallel. We believe that SenseMaker offers a way to directly and empirically investigate complex systems of engineering education at the local and even national level by "combin[ing] first-hand narratives with the statistical authority of quantitative data" [2].

A shift toward conducting research with *rather than* on *students*

In parallel to the increasing interest in narrative in the engineering education research community, and calls to examine engineering education as a complex system, there is also an emerging interest in more collaborative approaches to conducting research *with* rather than *on*

students [32, 55]. Some authors frame this type of work through the lens of participatory action research (PAR), which can be described as "a methodology for knowledge production that is based on participants' roles in setting the agenda, involvement in data collection, analysis, and interpretation, and control over the use of outcomes" [56].

Our work on "The Engineering Experience Project" at UGA was conducted with students from the beginning. As we have described elsewhere [5], undergraduate students and faculty collaboratively developed the signification framework. Undergraduate students also created the online survey and managed the first round of data collection. This level of collaboration aligns with the principles of PAR. While not all SenseMaker studies involve participants at all stages of the process, all SenseMaker projects *do* work collaboratively with participants in the third iterative step illustrated in Figure 1 (i.e., Sense-Making). According to Van der Merwe, et al. [2]:

> "Collecting sensemaking involves returning the information to a wider audience to solicit reflections on the emergent patterns and what underlies them . . . Some development practitioners consider this participative collective human sensemaking process, with actors in the system, as the core of the methodology."

We believe that the participatory nature of SenseMaker makes it inherently suited for research projects that are committed to working with students as partners and converting research findings to action and institutional change.

Prior implementations of SenseMaker

SenseMaker has been used in a diversity of contexts including, international development, crisis management, community planning, corporate settings and, more recently, higher education. At the time of writing this paper, the Cognitive Edge website provided live links to eleven past projects (see: https://cognitive-edge.com/sensemaker/). In the following section, we briefly describe two of these projects to provide readers with some insight into the different types of settings that have been sites for SenseMaker studies. We also discuss a third study that was recently funded by the NSF. We then discuss an implementation of SenseMaker in higher education.

Outside of higher education

Girlhub. Girlhub is an international organization dedicated to improving the education and welfare of girls and young women in Africa. To gauge the effectiveness of its programs and the practicality of SenseMaker in this setting, Girlhub employed several SenseMaker surveys in Rwanda and Ethiopia from 2011 to 2013. Through insights drawn from these stories, Girlhub was able to identify key issues hindering the girls and found these countries to be highly suitable for the SenseMaker process. In this project, story collectors with iPads went door-to-door to orally collect micro-narratives. This approach was particularly effective in regions with limited internet access [57].

Using stories to increase sales at Pfizer. Pfizer is an international pharmaceutical company. In 2010, it sought to improve the sales of a specific product in the European market. Believing that

the success of the product was dependent upon the sales representatives, Pfizer used a SenseMaker survey to collect anecdotal data from 94 sales representatives across 11 cities. It then used the results to form a series of workshops targeting areas of improvement with the hope of increasing sales. Pfizer used "anecdotal circles," where participants shared stories in a group setting, to allow stories and ideas to emerge organically. This approach helped Pfizer gain a better perspective of their sales representatives' experiences [58].

NSF-Funded project "CRISP 2.0 Type 2: Collaborative Research: Integrated Socio-Technical Modeling Framework to Evaluate and Enhance Resiliency in Islanded Communities (ERIC)". Hurricane Maria caused catastrophic damage to the infrastructure of Puerto Rico and demonstrated the need for a framework and methodology that is capable of assessing preparedness for extreme climatic events. To address this need, the NSF funded the "Enhancing Resilience of Island Communities (ERIC)" project (Award no. 1832678). The first step of this project involves using SenseMaker to gather micro-narratives from local citizens who were impacted by the hurricane Maria. These micro-narratives will inform the creation and implementation of a model to increase the resiliency of coastal communities in the face of future extreme events.

Inside of higher education

While we are not aware of any publications that report on the use of SenseMaker in higher education, we are familiar with efforts at Georgetown Univeristy.

In 2018, the *Hub for Equity and Innovation in Higher Education* partnered with the *Georgetown Scholarship Program* at Georgetown University to launch the "Student Belonging Study." The purpose of this study is to examine attitudes of belonging among first generation college students through analyzing micro-narratives collected using the SenseMaker approach. According to a website that describes this study, "the results of this work will be used both for internal improvement to first-generation student support services and to share with other college campuses seeking to understand ways to support first-generation students on their campuses" (https://futures.georgetown.edu/belonging-survey/).

Insights from "The Engineering Experience Project" at UGA

In this section, we describe what we believe are the three most promising affordances of SenseMaker as well as the three most significant limitations of the approach. These insights are written from the student perspective, led by the second author of this paper, and come from our shared experiences with designing and implementing "The Engineering Experience Project" at UGA. Hearing the student perspective is important because the success or failure of a SenseMaker project like the one we are conducting at UGA, which focuses on student experiences, depends on how students perceive the value of the approach.

Affordances

A valuable data gathering tool. Individuals, organizations, and societies are socially complex entities. As a result, analyzing and drawing conclusions from these entities is inherently difficult.

Mass surveys can often only provide insights at the macro scale, and even when trends are discovered, the underlying causes of these trends may still be a mystery. Although not fool-proof, the SenseMaker methodology can be a significant tool in identifying trends and their possible root causes.

The major advancement of SenseMaker over traditional surveys is how it collects and organizes data. While a traditional survey may consist of a lengthy questionnaire and a small textbox for additional details, the story and its analysis are the bulk of the SenseMaker survey. Often when researchers study a specific subject, initially the amount of data they accrue is limited by what they know about the subject and the breadth of their questions. Therefore, researchers will do background research, perform experiments, and conduct interviews to get a better understanding of the subject and ask more potent questions. The SenseMaker methodology approaches this process somewhat differently. Every SenseMaker participant is prompted to write a story pertaining to the subject at hand. The prompt is designed to be open-ended and avoid bias—giving participants a blank space to describe their experiences without an objective is a powerful tool. In this way, the value of the data does not rely on the researcher's preconceptions, and it may also bring intriguing elements to light that traditional surveys may have otherwise overlooked.

Once the data is collected, the stories along with accompanying triads, dyads, and stones are combined to provide a holistic view of the subject. In most surveys, drawing conclusions from text prompts can be difficult, requiring researchers to tediously sift through qualitative data. In SenseMaker, however, the triads, dyads, and stones provide a means of visualizing the stories, with user inputs from each participant forming diagrams that can help identify different aspects of stories and how they compare to other stories, enabling text prompts to contribute to a holistic perspective.

Novel survey design. In traditional surveys, once all the data is collected, the researchers are left to interpret the data and draw logical conclusions from these findings. While SenseMaker still requires analysis from researchers, it challenges these conventions by allowing the participant to interpret their own stories using triads, dyads, and stones.

In many areas where SenseMaker is employed, there may be a plethora of variables, both known and unknown, that are influencing the situation or environment. For "The Engineering Experience" at UGA, there was pre-existing data on student academics, but knowledge on what affected student performance and overall health was severely limited. As a student of the same institution, it was easy for me to have preconceptions and make predictions about how my fellow students would respond, and under a traditional survey, these biases would have likely had more bearing on what conclusions we came to. With SenseMaker, the ability for students to not only write about a topic of their choosing but also point out qualitative alignments supplements any gaps in pre-existing knowledge and protects against bias.

When the participant analyzes his or her story, the triad, dyad, and stone data can tell researchers more than the story itself. A participant analysis points out specifically how the participant feels about the events in the story. This is especially important if the participant uses sarcasm or confusing diction in their story, as the additional data can help decipher important aspects of the

stories. These analyses also display what portions of the story are most important to the participant. For instance, one of the participants in "The Engineering Experience Project" wrote a story with a miserable tone throughout, but ended it with a hopeful statement. It is logical to assume that the story's purpose was to project the person's dread since it made up a vast majority of the story, yet the person's triad data closely aligned with the final statement. This signifies that the person's feelings of hope outweighed their dreadful feelings, completely altering how we saw this story.

Agency. Despite researchers' best efforts and intentions, mistrust is a limiting factor when conducting surveys. It can be daunting to give a stranger a portion of one's own personal information, and especially so if the participant is not aware of the researcher's plans for the data. In fact, when I was having conversations with other students about "The Engineering Experience Project" SenseMaker survey, the most common question was "what are you going to do with the data?" SenseMaker can remedy this effect by involving the participants in the research process.

When I was talking to college classes about "The Engineering Experience Project," the students applauded me as I finished my presentation, despite not making any promises of reform. They were excited that students were being involved in the investigation of student success in the College of Engineering. Because SenseMaker allows participants to interpret their stories, the participants get a feeling of agency as they can directly control the results, increasing participant receptiveness and improving overall confidence in the study. If a participant is invested in the study, then the participant will want to ensure its success, so subsequent surveys and other related activities may be more fruitful. When marketing a SenseMaker survey to your target audience, agency can be a major selling point.

For organizations such as Girl Hub, this approach to analyzing data can support its mission:

> "Girl Hub first used the methodology in Rwanda in 2011 as it aligns with the value that Girl Hub places on using research processes with girls at the centre – elevating their voices and recognising their expertise in their own lives. Using the SenseMaker® approach, storytellers conduct the primary analysis of their own stories, greatly reducing the potential for interpretive bias and encouraging stakeholder involvement."

In the case of Girl Hub, it wants the disadvantaged women of these regions to be the catalyst for their change, so applying a SenseMaker survey to this context complemented the organization's goals.

Limitations

Buy-In. As a university student, I cannot count on my hands how many advertisements regarding surveys I have seen in the past month. Survey participation overall has dropped over the past few decades [59], and if SenseMaker is marketed incorrectly, it can be easily portrayed as just a regular survey, and this can hurt the story count significantly. When piloting our survey, we chose 10 people within our peer groups to test the survey, providing a $25 Amazon gift card as compensation for their time. All 10 people confirmed that they had participated. Incentives such

as gift cards have shown that they can improve response rates in surveys, though one can imagine that this can become expensive once more people participate.

When we began our first public SenseMaker survey, we transitioned advertising methods to reach a larger audience: we removed the incentive, and we advertised in flyers, mass emails, and newsletters. Unfortunately, with over 2200 students in the College of Engineering, we only managed to get 5 participants in the first week and participation ceased thereafter. Though the lack of incentives likely decreased the potential number of students, we believe that the difference in participation was the lack of personal connection to the survey. SenseMaker goes beyond the scope of a typical survey, considering the participants' perspective and giving them agency, but if the marketing does not meet SenseMaker's level of depth, then it will be treated like a typical survey. As seen in the pilot, participants are much more receptive to SenseMaker surveys if it is facilitated by someone they recognize rather than a faceless figure within their organization. This was confirmed later in our first launch when we employed a new tactic: at the beginning of my engineering classes, I would publicly advertise SenseMaker to my classmates and answer questions they had about it. This not only associated the survey with a person the audience knew, but it also demonstrated that the data would be collected and handled by a fellow student Within two days, the number of participants tripled. We are now developing new ways of using face-to-face connections to boost participation, such as story circles and workshops, as we believe that maintaining personal connection at all stages is the key to collecting useful SenseMaker data.

Novelty. When it comes to conducting surveys, the SenseMaker methodology is relatively cutting-edge, though this unconventional style of survey can cause confusion if precautions are not taken. The advantage of traditional surveys is that they are formulaic: multiple-choice questions and Likert scales (Strongly Disagree to Neutral to Strongly Agree) are staples of survey design, and this uniform structure allows participants to easily navigate the questions asked. SenseMaker asks much more involvement from the participants. Not only do participants have to reminisce on a recent event, but they must also conduct their own analysis on the story. While the average survey time during our piloting phase was reported to be roughly 15 minutes (on par with our estimates), some participants reported spending up to 40 minutes on the survey. In one of the feedback responses, a participant stated that writing the story was the most time-consuming sections. This was because he or she felt that the story prompt was too open-ended and wanted to ensure that the story was well-thought-out. Open-ended story prompts are necessary for the SenseMaker process, as it reduces inherent bias in the survey, but the prompt must also help segue into a story.

According to the feedback from our pilot study (with the 10 participants discussed above), other participants found that the prompts for the triads and stones were confusing, and we attributed this to heavy usage of SenseMaker terminology. The terminology, phrases such as "signification framework" and "stones," is nuanced, but not considered colloquial. Researchers developing surveys for SenseMaker would likely know the lingo extensively, but it is not safe to assume that participants will know what to do when faced with foreign elements such as stones. Therefore, researchers must ensure that any foreign term is properly defined and instructions for using elements such as triads are clear and descriptive. For instance, referring to stones as "circles" and

going in-depth with each component of a stones diagram will significantly ease the burden of participants using SenseMaker for the first time.

Technical. When beginning the web development of a Sensemaker survey, one will find that the SenseMaker suite lacks the technical fidelity of other common software. The survey is built through the use of "widgets," specialized elements that fulfill every interaction the participant has with the survey, such as changes pages or inputting triad data. When clicked on, each widget has a specific set of values and parameters that can be altered. The SenseMaker Designer Manual is integral to SenseMaker development, because it lists the function of each widget as well as the purpose of each parameter. These parameters are set via HTML, and implementing parameters incorrectly can cause the widget to malfunction during surveys. This process can become overwhelming for those without a basic knowledge of software development.

Due to the sensitivity and confidentiality of the data moving through the SenseMaker database, SenseMaker has taken multiple measures to ensure the security of the software, but at the cost of flexibility and personalization. Though the list of widgets is fairly extensive, there is no option for a custom widget and the designer prevents you from applying any sort of script to the widgets. This requires the designer to be extra creative when a widget needs to perform a function outside of its normal use. Uploading files can also be a hassle. Every file in a SenseMaker survey is stored on the SenseMaker database, but uploading files is not as simple as using an upload feature. All external files must be facilitated by the SenseMaker Support, which will then give you file paths for those files. Though the Support team typically responds and completes the task within the next business day, a minor tweak to a file can set the whole project back. In addition to files, manipulating the survey beyond the widgets requires contacting the Support team. Resizing pages and files must be done by Support as well. In my experience designing a SenseMaker survey, I found the Support team to be very helpful, but the constant need for assistance was likely dizzying for both parties.

Next steps and concluding thoughts

The purpose of this paper was to start a conversation about the affordances and limitations of using SenseMaker to investigate and transform cultures and practices of engineering education. By describing our experiences with using this approach, we hope to have provided sufficient information for readers (faculty and students alike) to begin reflecting on how SenseMaker might contribute to improving student experiences in engineering programs. At this point in our project, we cannot give a definitive answer to the question of whether the utility of SenseMaker justifies the cost. As we have discussed above, SenseMaker has promising affordances and significant limitations. We are committed to trying to overcome these limitations as we continue our work through 2020.

We welcome interested researchers to contact us if they would like to learn more about anything we have written about in this paper. For example, if teams of faculty and students are interested in using our signification framework, either at their own institutions or as part of a cross-institutional study, we are open to sharing and/or collaborating. As we progress with our project, we will continue to share our experiences with SenseMaker with the engineering education community.

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