Enhancing Research Quality through Analytical Memo Writing in a Mixed Methods Grounded Theory Study Implemented by a Multi-Institution Research Team

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***Abstract*—In this Full Research Category paper, we will provide a detailed description of how we are using analytical memo-writing within a mixed methods grounded theory study. The goal of our work is to identify key elements from undergraduate research experiences (UREs) that can be translated into the classroom by exploring the connections between engineering students' researcher identities, perceptions of research, and epistemic thinking within the context of UREs. The qualitative phase of our study which is the focus on this paper takes a grounded theory approach as we explore our research questions using in-depth interviews. Interviews were conducted by researcher pairs, transcribed, and cleaned. Preliminary analysis, which included initial coding, was conducted by researcher pairs to increase the validity of the analysis and facilitate analytical discussions between researchers. After initial coding, the researcher pairs constructed analytical memos with three parts: (1) summary of the participant (factual representation), (2) summary of salient themes/codes/analysis, and (3) connections of themes/analysis to other participants. We are using these memos to facilitate a constant comparative approach across participants, communicate and understand complex relationships between concepts, and enhance the development of our grounded theory model. As part of our description of our analytical memos, we provide details and examples from our study for each part of the memo. We also discuss the ways in which we have found the analytical memos to be helpful in our analysis. In particular, we discuss our use of the theoretical coding (three-part coding where you identify context, mechanism, and outcome) and magnitude coding (quantify qualitative data by creating Likert-type Scales for specific concepts) of our memos, which allow us to explore relationships between concepts and produce empirical support for the connections within our grounded theory model.**

Keywords—grounded theory, mixed methods, undergraduate research experiences

I. Introduction

Our work is classified as a mixed methods grounded theory study. As such, we pulled approaches from both domains to guide our work. Below we detail the use of memos in both mixed methods and grounded theory methodologies.

Mixed methods studies integrate elements of quantitative and qualitative methods to better understand a research question compared to employing either method alone [1]. Central to many definitions of mixed methods research is the idea of mixing, which are the ways that the quantitative and qualitative data are embedded, integrated, or merged at different stages of the study [2]. Qualitative and quantitative strands within mixed methods designs can be integrated to different extents, but any integration can be considered mixed methods [3]. "Qualitizing" quantitative data is one way to integrate numerical quantitative data with qualitative data from sources such as interviews, observations, or documents [3]–[5]. As part of a larger research study, we qualitized participants' numerical researcher identity self-ratings by asking them to define the ends of the measurement scale and explain why they chose their researcher identity ratings in an interview [6].

Grounded theory studies allow researchers to generate and expand theories through the use of rich qualitative interview data [7], [8]. This methodology requires specific researcher actions, including the simultaneous collection and analysis of data using an iterative process, use of comparative methods, use of data to develop new conceptual categories,

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and systematic data analysis to develop inductive categories [7], [8].

One research tool that is used to support researchers in the various aspects of grounded theory methodology is memo-writing. Memo writing is one of the core dimensions of the grounded theory process and the development of theory. Analytic memoing is a type of informal, reflexive writing or visualization that is constructed to reflect analytic thought and heighten theoretical sensitivity as the process of data analysis is unfolding [7], [9], [10]. Intended to promote the movement from the descriptive to a higher level of abstraction and the process of theory development [11], they are not intended to describe the social worlds under scrutiny, but to conceptualize it in narrative form [9]. During the process of their construction, memos can also serve to reveal gaps in the data and direct future theoretical sampling [8]. They can enhance reflexivity about standpoints and assumptions [8] and how these might interact with interpretations of the data. In the methodological literature, language about memoing is almost always phrased within the context of the individual researcher. Memos are assumed to be narrated records of a single theorist's analytical conversations with him/herself about their research data [11]. However, its most influential role in the mixed methods context is to provide a vehicle that facilitates conversations between members of a research team [12].

In mixed methods, an integrated memo links different sources of qualitative and quantitative data, often in case profiles and, in the process, shifts attention from isolated variables to relationships between the variables and the case as the unit of analysis [13]. These memos facilitate cross-case comparisons [11]. They can be qualitatively and/or deductively coded and serve as secondary source of data when cited in a publication, such as when they are used to document the evolution of a core category or line of thinking [14]. After the theoretical model is developed, integrated memos can provide a type of "reality check" that suggests which parts of the initial model are warranted, and which are interpretations do not reflect the participants'' experiences. The explanatory power of an analytical memo is enhanced as it is refined during the process of being reviewed and modified by multiple researchers [15].

In this paper, we will detail how we used analytical memo-writing in a mixed methods grounded theory study to build a theoretical model describing the connections between engineering students' perceptions of research, research epistemologies and researcher identities in the context of undergraduate research experiences (UREs). For this study, we collected both open- and closed-ended survey data followed by interviews. These analytical memos enhanced many aspects of our collaborative data analysis approach, including theoretical coding, theme generation, and model building.

II. Methods

While the primary reason for writing analytical memos was to help us move our data analysis to a higher level of abstraction, we also found these memos to be an efficient way for coders to communicate their analysis of interview transcripts to the rest of the research team. As such, authoring the analytical memos was a collaborative effort (**Figure 1**).

To facilitate the description how memos were constructed, we provide definitions of key terms that the research team used and definitions of the roles of the researchers in **Table 1**. As the research team for this project was distributed between three institutions and the amount of involvement varied from researcher to researcher, the roles needed to be well-defined and communicated across the research team.

Four researchers (two from Institution 1, two from Institution 2) conducted the interviews as pairs. We refer to these researchers as "Interviewers". After the interview, transcripts were made and then deidentified. Once the transcript was verified and uploaded to shared cloud storage, two "Coders" were assigned to analyze the transcript. Each coding team included one of the original Interviewers and a Coder from the other institution. Coding teams would switch for every participant to ensure that analysis was consistent across the two institutions and that interpretive coding remained as unbiased across coders as possible. Once Coders finished independently coding the transcript using an emergent coding process, they discussed their codes and formulated a narrative outline for the "Draft Memo". Each Draft Memo was constructed by four "Authors", consisting of the coding team and the two other Interviewers.

TABLE I. Definition of Selected Terms Used in Analytical Memo Construction

Term	Definition
Researcher	Any individual on the research project.
Interviewer	These are the individuals who conducted interviews.
Coder (Part of the coding team)	Any individual that read and coded the transcript using the methods described.
Author	Any researcher who read the transcript and contributed to the construction of the Draft Memo.
Reviewer	Any researcher who made comments or edits to the Draft Memo at any point. Unlike Authors, Reviewers did not construct the Draft Memo.
Reader	Anyone who read the Draft memo, but did not comment on or edit the Draft Memo.
Draft Memo	Initial memo draft written by the Authors.
Comment Memo	A Draft Memo that has undergone reviewing and editing by Reviewers.
Finalized Memo	A memo that has been revised to address any comments or edits provided by the Reviewers.

Once the Authors constructed the draft memo for the participant, it progressed through a revision process where research team members acted as "Reviewers" or "Readers". Reviewers focused on providing commentary on the analysis within the draft memo. This resulted in a Comment Memo, containing the comments and edits made by the Reviewers. Anyone who made comments or changes in the Comment Memo was considered a Reviewer, while members of the research team who read the Draft Memo and did not make any comments or changes were considered readers. Once the

Reviewers completed their commenting and editing, the Comment Memo was passed back to the Authors, who made appropriate changes to the document, resolving any differences in analysis or interpretation with conversations amongst the Interviewers. This resulted in a "Finalized Memo".

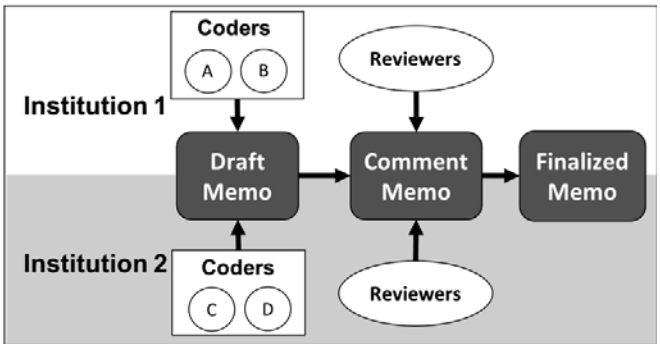

Fig. 1. The memo writing process took the analytical memo through several iterations, allowing different members of the research team to interact with the memo at each iteration.

The final memo consisted of three parts: (1) a factual summary of the participant and their research experiences (Participant Description), (2) a summary of the salient themes/codes/analysis (Coding Analysis), and (3) connections to other participants (Cross-Case Analysis). The construction of all of these sections are outlined below.

A. Section 1: Participant Description

This section provided a focused description of the participant to both provide context to memo readers who did not read the transcript or participate in the interview. This section was factual and included quantitative information generated from the participant's survey data, a general summary of the participants' research experiences (time in the research, role, tasks/duties, general topic of research), the participants' definition of research, how they viewed themselves as a researcher, and other salient details the authors felt were important. Authors explicitly noted if the participant expressed that the survey or the interview influenced their researcher identity rating. This section of the memo was also helpful to recall early participants when completing cross-case analysis for the final participants. Once this section was drafted, it was sent to participants for member checking to ensure the accuracy of the information. If participants suggested changes to the memos, the research team discussed the proposed changes and revised the memos as necessary according to the process described in Figure 1.

B. Section 2: Coding Analysis

The purpose of the coding analysis section was to support the researchers in moving from descriptive analysis to a higher level of abstraction, while enhancing reflexivity and revealing gaps in the data. As such, this section of the memo included a description of the participant's experiences and perceptions grounded in the outcomes of our emergent coding. This description also included descriptions of connections across concepts (codes) and key quotes from the participants.

Prior to writing the coding analysis section, the Coders discussed their emergent code applications and interpretation of the transcript. To construct this section, the two Coders reviewed each code application in the transcript and presented their interpretations to the other Authors. All four Authors reviewed the two Coders' analyses with a critical eye, pressing for compelling evidence for the interpretations in the form of direct quotes from the transcript. They focused on passages that were relevant to our research questions and passages that stood out as defining for a participant. Based on that discussion, the Authors co-constructed an initial draft of the coding analysis section.

Codes were not explicitly named in the memo; however, the ideas and themes revealed by the codes were addressed. The goal of our explanations was to ensure the memos would be able to stand on their own and be understood by researchers who did not themselves code the interview transcript.

C. Section 3: Cross-Case Analysis

The purpose of the Cross-Case Analysis section was to support further abstraction of the data by providing a place to describe and process connections between participants. While constructing the Participant Description and Coding Analysis sections of the analytical memo, Authors took note of participant perspectives that were either unique or similar to the views of other participants. In the case of memos written later in the research process, Authors would review earlier analytical memos to look for connections between participants. These perspectives were described in the Cross-Case Analysis section through the presentation of similar or contrasting cases. Analysis in this space was focused on providing connections between participants and documenting partial answers to our research questions. Like the Coding Analysis section, editing followed the same guidelines.

III. Results and Discussion

Below we provide examples of how analytical memos enhanced our data analysis and model building.

A. Analytical Memos Supported the Description of Relationships Between Theoretical Constructs

Below is an abridged example of the Coding Analysis section of a participant with the pseudonym Bay. This example highlights how the descriptive coding of disparate parts of the transcript were tied together in a logical flow of ideas, raising the analysis to a higher level of abstraction. Insights about the participant were supported with direct quotes from the interview transcript which are italicized below.

> Bay's image of what doing research looks like compared to her definition of research seems to be an important part of why she holds a conflicted view of whether or not engineering research exists. Bay's perception of research may come from her research experience senior year. She

talks about how she and her mentor constructed knowledge in her research experience:

> *Once he started showing me the graphs of the numbers, that's when I started to see, "Oh, those are acting exactly the same way." But it could have been just this one because that seems unexpected for them to act just the same way. It was after the third or fourth experiment that I started think, "Oh, we could actually be doing something really cool here."…So it wasn't like eureka moment at the very end, it was slowly seeing the build-up…*

At the beginning of the excerpt, we see Bay using epistemic thinking by comparing her collected data with prior knowledge. She follows this up with an epistemic metacognitive skill (EMS), monitoring the validity of just one measurement. As a result, she repeats the experiment multiple times to validate her results. The culmination of this knowledge construction was publishing the results. This seems to become part of Bay's epistemic metacognitive knowledge (EMK) about how knowledge is constructed in research: in order to be counted as knowledge, something must be shared, preferably as a publication. Publication positively affected Bay's researcher identity.

> *Well, one thing that really made me feel like a researcher was the fact that we got a paper published. That seemed like a research-y-esque thing to have it go into a scientific journal that says this is science. I was like, "Oh, wow. This totally is science, isn't it?"*

The direct quotes from Bay were taken from different parts of the transcript but when placed together in the narrative of the analytical memo helped us discover a relationship between two theoretical constructs that were guiding our data analysis: Epistemic Thinking [16], and Identity [17]. Finding this interaction between the two theoretical constructs played an important role in the construction of our grounded theory model.

B. Analytical memos Helped Us Integrate Our Quantitative and Qualitative Data

The analytical memos helped us to integrate quantitative data we obtained from surveys with qualitative data collected during interviews. In the survey, we asked participants to rate themselves on a Likert-like scale anchored between 1 (not at all) and 7 (yes, very much) in response to the question "Do you see yourself as a researcher?" similar to single items used to measure identity in other studies [18], [19]. During the interview, we "qualitized" [4], [5] the anchored quantitative item by asking participants where they would rate themselves on the same scale at the time of the interview. We also asked participants to describe their conceptualization of what a 1 and what a 7 meant to them. In this way, mixing the quantitative identity data with the qualitative interview data enabled us to take a deeper look at how students were conceptualizing researcher identity as well as students' reasoning behind changes (or consistencies) in their self-reported researcher identities between the time of the survey and the interview. Below is an excerpt from the analysis memo for the participant Taylor, revealing how and why her self-reported researcher identity had changed. The excerpt begins with a description of how Taylor conceptualized the researcher identity scale from the Participant Description section of the memo.

> Taylor sees a '1' on the researcher scale as someone who has minimal experience, does not put in much work, and has not made contributions to the community. She feels that a '7' is the opposite of what she described as a '1'. While she answered '5' on the survey, Taylor felt that she was more like a researcher now than when she answered the question on the survey.
>
> > *I feel like, from the time that I answered your survey to now, I feel a lot more like a researcher, just in the sense that I've had a lot more exposure in the last few weeks to doing engineering-related research, so I've been exposed to another field in that sense. If I answered seven for whatever reason on that, I would probably put myself at an eight or a nine right now.*
>
> Taylor initially answered a '6' during the interview but changed her answer to a '5' after some discussion.

The Coding Analysis section of the memo explains why Taylor changes her researcher identity self-rating during the interview:

> Taylor believes that there is no end of things in the world to learn, and so there is always room for a researcher to learn and grow. She understands that a researcher can be 100% a researcher in terms of their institutional identity, where their job is to research; however even the most experienced researcher has room to learn.
>
> > *I think it's really hard to say that you're ever at a full 100% researcher, but I think that's also because my interpretation of it is there's always room to learn and stuff and be exposed to other things. […] I think it's hard, now that I understand that there's so much out there in terms of research. I think you can be very skilled in the research that you do. And obviously if you're a researcher, you're a researcher. I'm not trying to discredit anyone from the work that they do, but I think it's just because I'm also thinking about it in terms of whether you have room to grow and whether you're fully experienced in all aspects of every sort of research ever. Maybe that's a seven for me, and I feel like that's really hard for someone to say, "Okay, I've done all these sorts of research and all these sort of fields and I know all sort of protocols*

and all sort of this," and I think that's just hard. But I guess that's experience-based. I feel like a researcher's still a researcher and you're still 100% in that sense.

Here, ideas flow from a conversation of how the participant defines research into a discussion of the participant's research identity and how she fits into her own definition of research. These ideas directly related to our research questions, and are important to consider together.

From the excerpt above, it seems that Taylor's perception of researcher identity is dependent on how broad one's experience in research is. At the beginning of the excerpt, she says that researchers can be skilled in the research they do, suggesting that they are good at research in their own field. Later in the excerpt, she says that a researcher at a '7' would have "[…] done all these sorts of research and all these sort of fields […]" Taylor recognizes that when she took the survey, she rated herself too high because she hadn't had enough experience with research. Now that she has done more research, she feels like she is able to recognize how much she actually does not know, and how she is not as strong of researcher as she had initially rated herself. She feels like she has grown a lot as a researcher, yet still has a long way to go.

I feel like, from the time that I answered your survey to now, I feel a lot more like a researcher, just in the sense that I've had a lot more exposure in the last few weeks to doing engineering-related research, so I've been exposed to another field in that sense. If I answered seven for whatever reason on that, I would probably put myself at an eight or a nine right now. It's just knowing more than I thought I knew… knowing more than I would ever be exposed to, if that makes sense.

The excerpts from Taylor's analytical memo above demonstrate how the memo was used to integrate our quantitative and qualitative data. Integrating these data helped to expose participants' dynamic conceptualization of the researcher identity scale. Additionally, the analysis memo helped to capture Taylor's reflection about her own researcher identity during the interview. Documentation of reflection in Taylor and other participants' analytical memos led to the inclusion of a reflection component within our grounded theory model.

C. Construction of Anlytical Memos Facilitated the Use of Constant Compartive Analysis

An important part of the grounded theory methodology is the constant comparison between participants during data analysis [8]. To illustrate how the analytical memos aided us in this process, we present an abridged example of a cross-case analysis of the participant we called Frances. There are a variety of comparisons made in this section between participants. This first paragraph compares the different meanings participants had when they rated themselves equally as researchers. This provided insight into how different participants with the same self-ratings held different views of what it meant to be a researcher.

Frances, Riley and Logan all rated themselves a 6 on the scale of "feeling like a researcher". While Frances believes that it is improbable that an undergraduate researcher can rate themselves as a 7, Riley and Logan believe it to be impossible for an undergraduate to reach a 7. Frances thinks it would be possible, but not "within the confines of structured undergraduate research." She believes the only way to attain a 7 would be for a student to start their own research project.

With regard to mentorship, Kelly felt like her identity is linked to the strength of mentorship, feeling like the lack of mentorship constricted her identity. On the flip side, Frances believed that her lack of mentorship allowed her to gain more experience and take on many roles within the lab, thus increasing her research identity. This idea of diverse experiences is also evident in Sam, who felt like her identity increased because of her ability to participate in different tasks and figure out what she liked and didn't like.

Above, we see that a comparison is made between participants with differing viewpoints. This type of cross-case analysis was important in highlighting the different perspectives between participants. These diverse perspectives revealed in the analytical memos helped to refine our data collection and analysis. The analytical memos also included documentation of likeminded views. This helped us keep track of important themes that were mentioned by multiple participants.

Finally, Frances is similar to other students in her perception of engineering vs. science research. Like Peyton, she sees science research as providing foundational knowledge that engineering research applies to produce products that help humanity. Frances is articulate with her distinction between science and engineering research, saying that science research finds out how things work, whereas engineering research has a creation aspect to it.

The Cross-Case Analysis section of the memo as a way for the authors to compare ideas across participants. In order to construct the cross-case analysis, authors would use their knowledge of participants that they interviewed or wrote memos about previously. As additional participants were interviewed, and as more memos were constructed, the Cross-Case Analysis section of the later memos became more thorough. This section of the memos helped draw out themes and other important ideas from the aggregated data.

D. Analytical memos Enhanced our Data Analysis and Model Building

Data analysis was guided by our theoretical frameworks. We used theoretical coding to integrate our descriptive, inductive coding with codes constructed under the guidance of our theoretical constructs [8] of epistemic thinking [16] and identity [17]. Integrating our inductive and theoretical codes anchored our analysis in the context of our theoretical constructs and drove the construction of our analytical memos. Co-coding using inductive and theoretical codes enhanced our meaning making by helping us to see connections between dissociated parts of the transcripts. These connections were described in our analytical memos.

The large size of the research team distributed between two institutions, and the differing theoretical expertise among individuals within our research team presented a substantial challenge to discussing the analysis of transcripts. The analytical memos aided these discussions by allowing all members of the research team to have a deep understanding of all participants without the need for every researcher to code each individual transcript. This allowed data analysis to be collaborative. Co-construction of the analytical memos by coders from both institutions facilitated well-rounded analysis by researchers with diverse experience. Discussion between coders during memo construction ensured the creation of quality Draft Memos that accurately portrayed analysis of the coders. These analytical memos laid the foundation for discussion of the analysis by the research team. Discussion of the analytical memos between Interviewers who were deep in the data and Reviewers who were farther removed from the data allowed the research team to leverage these differing perspectives. Integrating these perspectives enhanced the quality of our analysis, and assisted later processes such as theme generation and model building.

The analytical memos were used extensively in theme generation. To generate themes, each coder read through all analytical memos, constructing tentative themes. Coders then discussed the tentative themes to generate a list of refined themes. Coders confirmed that themes were salient through a process called magnitude coding [20]. During this process, coders revisited the memos with the list of refined themes, coding the magnitude each theme was represented within each analytical memo using a scale of weak- medium- and strong-representation. The finalized list of themes all had strong representation in at least one analysis memo. The list of themes generated from the analytical memos guided the construction of the grounded theory model.

E. Analytical memos Were Instrumental in Testing Our Model

Use of the analytical memos contributed to model testing by facilitating the verification of theoretical saturation, and theoretical sampling. To ensure that we had adequate interview data (especially given that we conducted fewer interviews than planned), and following the advice of the advisory board to examine transcripts out of order to avoid coding fatigue, two researchers not involved in the construction of the original themes went through the each analysis memo in random order and identified their own tentative themes. These themes were compiled and compared to the themes that the original coders developed to see if new themes had emerged that would require additional data to support them. No new themes emerged that could not be categorized under existing themes.

To ensure that our model was grounded in the data, we tested the model through a form of theoretical sampling [8], utilizing the analytical memos once again. Coders selected analytical memos from participants that they felt strongly supported the model and participants they felt would break the model. Using the analytical memo as a foundation, the coders constructed model-fit memos, which described how the analysis of the participant described in the analytical memos fit or did not fit the theoretical model. This analysis was instrumental in the refinement of the final grounded theory model.

IV. Implications

While the use of analytical memos impacted our work directly as described above, they also have broader implications related to conducting research, especially for projects across multiple sites with many researchers. Most importantly, these analytical memos provide a way to communicate a summary of the analysis to an entire team in an efficient manner to allow for critique and meaning making. While full research teams could spend time reading all transcripts and being fully involved in all stages of analysis, we know this is not realistic for large teams. These analytical memos provide a succinct and targeted summary of the key information needed for analysis so that all members of the team can discuss the key elements of the interviews and contribute to meaning making without being bogged down by transcripts. This is not to say that transcript are not important. They can simply serve another purpose in analysis if these memos are created.

The analytical memos also allow for levels of abstraction in the analysis that may not be possible with full transcripts or less structured memos. Because the memos focused in on the key elements of the participants' stories, we were able to focus on salient ideas and then abstract those ideas into themes and ultimately a model more easily. With full transcripts, this would be more difficult and with less structured memos it may be challenging for all memos of the team to understand the importance of the key concepts if they did not construct those memos.

Finally, we found the analytical memos to a great tool for on-boarding new researchers to the project. Over the life of this project, 15 researchers have contributed in some way. These researchers include faculty, graduate students, and undergraduate researchers all with differing levels of experience related to qualitative methods. Having new members of the research team read these memos opposed to transcripts to become acclimated with the data was extremely valuable. It also helped provide a structured process for open-coding which can be daunting and nebulous for inexperienced

researchers. This process of memoing has already been applied to other research projects and shows great promise as analysis technique especially for projects across multiple institutions with a variety of researchers.

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