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A Qualitative Methods Primer: A Resource to Assist Engineering Education Scholars in Mentoring Traditionally Trained Engineering Faculty to Educational Research

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A Qualitative Methods Primer: A Resource to Assist Engineering Education Scholars in Mentoring Traditionally-Trained Engineering Faculty to Educational Research

Abstract

This research methods full paper presents a primer on qualitative analysis methods intended to be a resource for experienced qualitative engineering education researchers to communicate the basics of qualitative research methods to traditionally-trained technical engineering faculty embarking on educational research initiatives. The recognition and growth of engineering education has drawn new researchers to the field—for example, in National Science Foundation Research Initiation in Engineering Formation (RIEF) grants, and CAREER Broader Impacts and Educational Plan activities—which require traditionally-trained faculty to develop engineering education research skills. Reflecting this shift, the number of qualitative research articles in engineering education reflects the increase in interest in qualitative methods and the need for introductory material for pivoting researchers. It has been the norm for engineering education researchers to partner with emergent and pivoting engineering faculty members to mentor them through this transition, but the process is often time- and resource-intensive. To meet this need, we have developed this primer on qualitative research methods that can be employed as an overview reading for traditional engineering faculty to orient them in early qualitative methods conversations.

This paper provides an overview and comparison of three common qualitative analysis methods: content analysis, thematic analysis, and grounded theory. For each analysis method, the manuscript provides a basic definition, historical contexts, common assumptions in the application, strengths and weaknesses, examples from engineering education, and additional resources. These three methods are discussed as commonly employed methods with common misunderstandings and misapplications that are often confusing for emergent engineering education researchers. Armed with an understanding of the similarities and differences in these methodological traditions, readers of the primer will be equipped to choose and evaluate their own qualitative methods and will be able to engage in future conversations about these more advanced and specialized qualitative methods (e.g., narrative inquiry, phenomenography/phenomenology, ethnography) in the future. The paper will provide a resource for emergent qualitative engineering education researchers to assist them in identifying their intended analysis techniques and can serve as a starting point for discussions with potential collaborators.

Introduction

This research methods full paper presents a primer of qualitative methods that is intended to be a resource for newer engineering education researchers or traditionally-trained engineering faculty embarking on educational research initiatives. The recognition and growth of engineering education has drawn new researchers to the field—for example, in National Science Foundation Research Initiation in Engineering Formation (RIEF) grants, and CAREER Broader Impacts and Educational Plan activities—which support traditionally-trained

Qualitative: Text or non-numerical data used to understand phenomena in depth through investigation of specific experiences, contexts, situations, and meanings generated by people.

faculty in development of engineering education research skills. The growing number of qualitative research articles in engineering education reflects the shift in use of qualitative methods and the need for introductory material for pivoting researchers. For instance, the number of qualitative research articles available through ASEE's PEER document storage system increased from 354 in 2012 to 720 in 2022. In the same time frame, each type of analysis more than doubled in the PEER system: content analysis grew from 30 to 74 articles, thematic analysis from 10 to 113 articles, and grounded theory from 29 to 69 articles. This shift, while exciting and welcomed from the engineering education community, also can lead to a burden on established engineering education researchers in teaching qualitative research methods outside of a classroom context.

These valuable collaborations typically require a great deal of investment, often uncompensated, on the part of the established engineering education researcher to teach, train, and mentor pivoting researchers. Therefore, this primer is intended to save time and energy for established engineering education researchers, while also being easy-to-digest for technically trained engineering faculty. From our unique positionality as rigorous qualitative engineering education researchers housed in a traditional engineering discipline, we have developed this primer over several years of interactions with dozens of technical engineering faculty and students interested in conducting qualitative educational research. This primer provides an overview and comparison of three common qualitative analysis methods: content analysis, thematic analysis, and grounded theory. Through this paper, pivoting or beginning engineering education researchers reading this paper will be equipped with an understanding of the similarities and differences in these methodological traditions preparing them to discuss, evaluate, and choose their qualitative methods as they engage in engineering education research.

This paper begins with a brief introduction to the role that epistemology plays in educational and qualitative research and a brief introduction to qualitative processes and the diaspora of qualitative research methods and traditions. Most of the paper, though, focuses on three commonly employed qualitative data analysis methods for newer engineering education research: Content Analysis, Thematic Analysis, and Grounded Theory, although common confusions and misunderstandings can lead to misapplication of method for pivoting engineering education researchers [1], [2]. For the purposes of this paper, the goal is to provide an accurate but high-level overview so users can compare the basics of these traditions: Each of these methods has extensive documentation in the form of textbooks and literature that we also recommend, though these are likely less approachable at the beginning for newer engineering education researchers.

Epistemologies in Qualitative Research

> **Epistemology:** The theory of knowledge that one holds on how knowledge is generated or identified with implications on what and how we *know* the world around us.

To begin our exploration of qualitative research, we first must discuss epistemologies with a brief introduction to some of the many epistemological stances available to qualitative researchers. A researcher's *epistemology* represents the theory of knowledge that one holds on how knowledge is identified. Traditional engineering training focuses on positivist epistemologies to answer *engineering* research questions, holding the assumption that *the truth* can be objectively observed, measured, and reported. In engineering education research, positivist epistemologies often align well with quantitative, statistical, and predictive methods of research. However, the types of data employed in qualitative research (e.g., interviews) hold different underlying assumptions about truth, since

they collect human stories about experiences. While this is not the place for a comprehensive discussion of qualitative epistemologies, the most commonly employed in qualitative are post-positivist and constructivist. A postpositivist epistemology assumes that there is an objective *truth* exists and that humans observe the truth from the imperfect viewpoint of context-dependent human fallibility, requiring conjectures of the truth which can be amended based upon additional observations and conjectures. Constructivist epistemologies, in contrast, assume that objective truth cannot be observed by humans and that all knowledge is based on the socially constructed models and observations of human minds.

While these philosophical considerations may seem esoteric, they inform how and why researchers choose to ask certain research questions, investigate certain topics, and which methods are chosen to answer those research questions to make meaningful advances in scholarship on those topics. All researchers carry their own epistemological alignments, regardless of whether they can articulate them!

The difference in epistemology may be impractical for measuring the heat transfer in an engineering system but are very important if researchers wish to understand *how students learn* heat transfer. Extending the example, the students in a heat transfer class experience the same class lecture: A researcher holding a positivist epistemology may propose that every aspect of 'the class' can be measured to discover the *true* learning experiences of students. They would likely ask research questions that could be measured quantitatively, aiming to understand the normative experience of students. Researchers holding a post-positivist epistemology may argue the truth of the class exists, but human measurement cannot adequately measure the differences in experience between students. They may ask research questions that can be answered by gathering human experience, perhaps using qualitative methods (interviews or otherwise), with the understanding that the findings from this research are locally bound. Researchers holding constructivist views may argue that each student's truth is subjective, based not in an objective reality, but in the shared social experience of the classroom in that particular semester and informed by each individual's perspective, including the researchers'. It is from the individual perspective that qualitative research discovers knowledge based in the perspective of humans in an attempt to better articulate human experience. For readers interested in a more in-depth consideration of epistemology, consider readings specifically addressing epistemologies (i.e., [1], [3]).

One of the most disruptive concepts in the shift between quantitative and qualitative research traditions is that in most qualitative research traditions, the researcher *is the instrument*, and that fact cannot be divorced from the interpretation or reporting of the data. Traditionally-trained engineering faculty may feel uncomfortable with this shift, with critics proposing that qualitative research is therefore purely subjective and therefore not valuable to the scholarly community (see Ross [4] for a critique of the epistemological values of traditional communities and barriers to broadening participation in CS and engineering). In contrast, qualitative methods for data analysis are deeply methodical, and while interpretative, are governed by deep traditions of formalized methods for data analysis when done well.

Quantitative: Using numerical data in the form of variables and relationships between variables to investigate phenomena in ways that can then be generalized to other contexts.

Instrument: What is used to collect data for analysis.

The General Process of Conducting Qualitative Research

Qualitative researchers seek meaning in qualitative data: interviews, textual responses from participants, artifacts, and other non-numerical sources. Because these sources of data are not numerical in nature, at first glance the qualitative research process can seem unrelated to traditional engineering research from a positivist scientific perspective. However, qualitive research follows the same basic scientific process: Developing a Research Question, Articulating a Research Idea, Forming Hypotheses, Collecting Data, Analyzing Data, and Interpreting and Reporting Data in publications.

Within the qualitative research process, each step shares similarities and differences with quantitative based research. First, a research question must be posed that is clear and answerable, motivated by what has already been done in prior scholarship and the gaps remaining to be filled. Second, a research idea proposes how the research question may be answered. Qualitative researchers often use theory (including theoretical frameworks or conceptual frameworks) to clarify the lens through which their research questions can be approached (See Magana [5] for more information.) The next step, generating hypotheses, holds a major distinction – often qualitative research does not have explicit hypotheses: Qualitative research seeks to interpret meaning from the data that has not previously been discovered – qualitative researchers often have little or no concrete idea of what meanings, patterns, or relationships between themes will be identified in a new data set. They are asking the research question because the meaning is unclear and requires new data and interpretation to provide meaning. At the same time, a qualitative hypothesis may still exist at a higher level: even that *"X type of data about Y topic/phenomenon from P participants will generate meaningful answers to my research question."* Then, the Data Collection stage requires clear, ethical (e.g., IRB approved, if including human participants), and structured data generation just as quantitative research; however, qualitative data comprises words or artifacts rather than numbers, requiring significantly different approaches to data analysis. Qualitative data analysis then uses well-defined methods and (often) theory to find meaning in the data. Finally, interpreting and reporting research findings requires the synthesis of clear, concise, and trustworthy conclusions which follow directly from the data.

Because qualitative data analysis is very different from the quantitative traditions most familiar to newer engineering education researchers, in this primer we focus on three common introductory methods for qualitative data analysis of textual data, especially interviews. As a note, there are other methods for analyzing artifacts, and there are also dozens of highly sophisticated methods for extremely nuanced and deep qualitative analysis, such as phenomenography, phenomenology, discourse analysis, and narrative analysis methods—all of which have their own traditions, procedures, and guiding foundational methodologists to cite, and their own epistemological underpinnings. For additional perspectives on qualitative research in engineering education try one of the following: Koro-Ljungberg and Douglas [2] or Slaton and Pawley [6].

Before we begin, some basic definitions are appropriate and will prove useful in identifying distinctions between methods. The term "Coding" in qualitative research holds a variety of meanings dependent on research method, analysis, research question, and researcher intention. At the most basic level, *coding* is defined as assigning meaning to a chunk of text – words, phrases, sentences, paragraphs, or passages (depending on the unit of analysis determined appropriate by the researchers) that can then be used to identify meaning in the data. Codes can be identified through a variety of approaches: *Inductive coding* approaches are where the researcher identifies

the meaning of the text and generates a code to describe or label that meaning. Conversely, *deductive coding* processes use existing theory, model, or existing literature to generate the code names such that researchers identify text which reflects components of the knowledge. Newer abductive approaches to coding work to augment existing theory, employing many aspects of an established theory and/or model but looking for areas by which theory can be expanded.

Through the data analysis process, qualitative researchers will develop a "codebook" of codes with standard definitions so that the entire dataset can be coded in a systematic fashion. This process is often highly iterative in nature, often with sub-codes resulting to enable the capture of nuance in data. Multiple coders should be able to apply the definitions and codes consistently across a data set. While there are different ways of handling multiple raters [7], some qualitative researchers prefer to "code to consensus" if there are discrepancies between coders [8], while some turn to positivistic definitions of consensus by calculating interrater reliability (such as Cohen's Kappa [9]). While it is possible to conduct the coding process by hand on paper, there are several software packages available to assist researchers and teams of researchers (such as NVIVO and Dedoose). Once coded, codes can then be used to identify themes. Themes represent the meanings identified by the researcher considering theory, literature, and the interesting patterns of responses emerging from the coded data. Theme generation can be difficult, time consuming, and often requires iterative reflection and analysis to ensure high quality in reporting the meaning of the data.

In sum, newer researchers in engineering education and educational research should be aware that the term "coding" in qualitative research will always be used to mean "categorization of units of qualitative data" with the goal of finding themes and relationships between themes in qualitative data. However, the different traditions of data analysis methods (e.g., Content Analysis, Thematic Analysis, Grounded Theory) will mean that the ways in which these themes are generated will be different.

Comparing and Contrasting Qualitative Data Analysis Methods: Content Analysis, Thematic Analysis, and Grounded Theory

In this section of the paper, we present the three qualitative analysis methods of interest systematically. For each analysis method, we provide basic definitions, relevant historical contexts and philosophical underpinnings, common assumptions in application, strengths, weaknesses, and examples from engineering or education. It should be noted that methods are constantly evolving and under development in multiple disciplines simultaneously (e.g., in education, sociology, psychology, and discipline-based educational research like engineering education), and so there are ongoing debates and scholarship related to some of these methods conversations. While the goal is not necessarily to debate these issues here, a note about emergent conversations, where relevant, is included in these sections.

Content Analysis

***Basic Definition*:** Hsieh and Shannon offer one of the most comprehensive and approachable texts for content analysis, in our experience, rather than having to sort through multiple textbooks for information. Their definition of qualitative content analysis proposes that it is "a research method

for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" [10, p. 1278]. Content analysis uses categories, codes, and themes from text data (i.e., website, newspaper, interview transcripts) to infer patterns and meanings from that data. In content analysis, codes are usually descriptive words or phrases, such as "engineering education." A theme might come from how the phrase is used or the context of the phrase. In this example, the code might lead to themes about researcher interests or university programs based on the context of the code and how it can then be categorized to identify meaning in a set of text. In the simplest way, content analysis seeks to categorize examples of what information the text contains. Hsieh and Shannon [10] divide the diaspora of content analysis into three types: conventional, summative, and directed that provide options for researchers to identify the best process for their research questions. Summative content analysis refers to methods of quantifying qualitative data (e.g., counting instances of particular codes) to infer meaning; directed content analysis refers to the process of seeking data which fits existing theory, and conventional qualitative content analysis is interested in grouping codes into overarching themes, similar to thematic analysis methods (which will be described next.) In general, content analysis methods often seek to answer questions that look for dominant categories, asking "What …" and "How often…" a phenomenon (or parts of a phenomenon) occur in a given research setting.

***Historical Context*:** Content analysis began as a quantitative method for analyzing qualitative data in which coded text could be counted or summarized by numerical means and understood through statistical analysis [11]. The first applications were to identify patterns in newspaper coverage. While quantitative content analysis is still employed today, and possibly useful in some applications, there is arguably a deeper level of understanding about human learning and behavior that can emerge through the more interpretative traditions of content analysis.

***Common Assumptions in Application*:** The foundational assumption within the use of content analysis is that by establishing a set of common codes, organized into themes, large amounts of qualitative textual data can be considered within fewer content categories [12] as a route to identify themes or patterns in the text driven. Content analysis has variations based on research tradition with some common steps: defining the categories, coding process and the coder training, implementation of coding, and analyzing the coded material [13]. Within coding, inductive and deductive analyses may be useful depending on the existing prior knowledge on the research topic [14].

***Strengths & Weaknesses*:** Content analysis provides systematic analysis of text data while allowing for an organic project-specific approach to categorization of data [15]. Given the history of content analysis, researchers may choose to include quantitative analyses of categories in addition to the qualitative analyses. One potential pitfall for content analysis occurs when researchers focus on counting content (quantitative or summative content analysis) without engaging in qualitative analysis of the categories identified through qualitative content analysis. Content analysis provides an ability to handle larger amounts of text data, potentially from a wide variety of sources, though relatively large datasets can create problems in developing systematic approaches to data management. There are also some issues that arise in content analysis: Linguistics can complicate categorization in content analysis in which the obvious or preferred reading should be used [16]. However, polysemy (multiple meanings of words), irony, slang, and sarcasm, among other linguistic variations, may increase or complicate categorization attempts. In

addition, the simplification of data into categories may not capture the depth of meaning or context of coded data.

In general, a lack of specific structure or procedures for content analysis may become confusing or lead to errors for researchers new to the process [12], especially without guidance, and the relationship of content analysis to theory can also be confusing. Scholars who have been trained in traditional science and engineering venues that are newer to qualitative methods may find themselves oriented toward "counting" numbers of occurrences and should be aware that this summative content analysis is one way of handling the data but potentially is not as rich as either the other traditions of content analysis or other qualitative data analysis methods.

***Future*:** Advances in Artificial Intelligence and Machine Learning- supported qualitative analysis apply directly to content analysis, especially with the emergence of topic modeling and other Natural Language Processing tools to be able to categorize large amounts of text (assuming a sufficiently trained algorithm). As AI programs become more advanced, we expect to see increasing use of AI-assisted content analysis, particularly for use on large scale data such as social media platforms, since AI programs have the ability to scan vast amounts of data to categorize text with limited intervention from human programmers. However, there are emergent conversations on whether and how technology can contribute to interpretative research if the human researcher is to be the instrument for interpretation [17], [18].

***Examples of content analysis in action*:** Rios et al. [19] used web-scraping to collect job advertisements (n = 203,272) and identified the skills required to be hired with oral and written communication in the highest demand. This research demonstrates how collecting frequency data across a very large qualitative sample set can provide direction for educational institutions and educators as well as job seekers.

Pawley, Schimpf, and Nelson [20] used content analysis of gender research in the Journal of Engineering Education to identify categories of gender-related research in engineering education. This example demonstrates the utility of content analysis to identify trends and gaps in the ways in which topics are investigated across a large body of research.

Useful methods texts and resources for content analysis methods:

[10] H.-F. Hsieh and S. E. Shannon, "Three Approaches to Qualitative Content Analysis," *Qual. Health Res.*, vol. 15, no. 9, pp. 1277–1288, 2005. Thematic Analysis

[13] L. L. Kaid, "Content Analysis," in *Measurement of Communication Behavior*, P. Emmert and L. L. Barker, Eds. New York: Longman, 1989, pp. 197–217.

Thematic Analysis

***Basic Definitions*:** First, thematic analysis is often confused or conflated with content analysis [21], [22] requiring clear distinctions between these methods, especially because the conventional qualitative content analysis methods closely resemble thematic analysis. Thematic analysis is most basically "a method for identifying, analyzing and reporting patterns (themes) within data" [23]. While this may sound similar to content analysis, thematic analysis focuses on the meanings of life experiences reported by participants. A key distinction between content and thematic analysis is closely linked to the phrasing of the research questions and the root of what the researcher hopes

to better understand: Content analysis answers 'what' or 'how often' questions (e.g., what courses and elements of courses do students talk about when they discuss their entrance to major experiences?) In contrast, thematic analysis is more equipped to answer 'why' or 'how' questions (e.g., Why do students discuss passing courses differently? Or How do students' experiences in introductory engineering courses influence students' career intentions?) Thematic analysis should identify explicit and implicit ideas within data to develop themes that then provide answers to the research questions [24]. Explicit ideas are straightforward expressions repeated within the data. Implicit ideas require digging into the meaning behind the words to identify unspoken truths that appear in subtle ways in the data. Coding contributes to systematically identifying these ideas that can then be coalesced into a theme, which should clearly provide answers to the research questions.

***Historical Contexts*:** Relatively new, thematic analysis was first described by physicist and historian of science, Gerald Holton in the 1970s [25]. However, the majority of attention, description, and formalization of thematic analysis in qualitative social science research followed Braun & Clarke's [23] foundational article. Due to the relatively new formalization, thematic analysis may still be approached differently by some researchers. For instance, here we focus on thematic analysis specifically as an analysis or data interpretation approach while others may approach thematic analysis as a research method.

***Common Assumptions in Application*:** The six phases of research when applying thematic analysis include becoming familiar with data, generating initial codes, searching for themes, reviewing potential themes, defining and naming themes, and producing the report [23], [26]. Similar approaches have been described by Guest et al. [24] and described as 'applied thematic analysis'.

***Strengths & Weaknesses*:** Thematic analysis proves highly flexible in applications. However, such flexibility requires a clear stance on epistemology and coding strategy (inductive, deductive, a priori, ad hoc), the rationale for research choices, and then consistent application of choices throughout the research to demonstrate the quality and trustworthiness of the analysis [23], [27], [28]. Similarly, thematic analysis is compatible with many epistemological stances and coding strategies. Thematic analysis may be used with large samples, however, identifying meaningful themes may become increasingly difficult.

Thematic analysis has a lack of systematic approaches accepted across disciplines and contexts of research [27]. While flexibility is a strength, it may lead researchers to become inconsistent or even incoherent in describing how themes are developed from the data [27]. Thematic analysis can be prone to identifying weak themes that simply reflect the researchers' questions (i.e., we asked about X and participants talked about X) or focus on the surface meaning of participants' responses without digging deeper to understand the full context and meaning behind the words. Without proper interpretation through theory, weak themes may lead to the researcher missing nuances within data and themes that would be more identifiable using more complex analysis methods.

***Examples*:** Lyon and Magana [29] used thematic analysis to identify the types of computational thinking outcomes used when students build computational models. The example clearly outlines the process from coding categories to themes in the data.

Huff, Zoltowski, and Oakes [30] demonstrate the utility of thematic analysis within mixed-methods research. Specifically, the authors explicitly outline the coding process, quality, and how

thematic analysis improved the researchers' ability to understand participant experiences with EPICS, a service-learning engineering experience.

Useful methods texts and resources for thematic analysis methods:

[21] V. Braun and V. Clarke, "Can I use TA? Should I use TA? Should I not use TA? Comparing reflexive thematic analysis and other pattern-based qualitative analytic approaches," *Couns. Psychother. Res.*, vol. 21, no. 1, pp. 37–47, Mar. 2021.

[27] L. S. Nowell, J. M. Norris, D. E. White, and N. J. Moules, "Thematic Analysis: Striving to Meet the Trustworthiness Criteria," *Int. J. Qual. Methods*, vol. 16, no. 1, Sep. 2017.

Grounded Theory

Basic Definitions: Grounded theory provides researchers an opportunity to delve deeply into a specific set of data with the intention of developing a highly descriptive account of what is happening in the data in such a way that a theory can be produced [16], [31]–[33]. Traditional grounded theory requires inductive coding in which codes come directly from the data. Deductive coding is not possible because existing theory or literature does not provide potential codes for the researcher. In grounded theory, themes arise from codes and are used to develop a theory to explain the phenomenon of interest. There are disagreements in the research community as to whether grounded theory is a methodology (i.e., carries its own set of goals and values that affect the research design, research questions, data collection, data analysis, and interpretation), or whether grounded theory at this point in time is simply a method of analyzing data that is synonymous with the "constant comparative method" of data analysis.

One major difference between grounded theory and either content analysis or thematic analysis lies in the use of prior literature and theory. While in content analysis and thematic analysis, there should be a theory or framework guiding the study, to use grounded theory well, researchers must make a strong claim that existing theory does not yet exist to well-explain phenomena; however, they typically address prior literature and "sensitizing concepts" [34] but must be careful to justify the need to create a new theory.

Another major difference between grounded theory and either content analysis or thematic analysis is in the data collection procedure itself. While newer researchers may approach this differently, according to traditional grounded theory methods texts, the researcher must collect a reasonable amount of data to justify the sample size, and code the data through emergent open and axial coding through the constant comparative method. If at any point a new theme emerges, the researcher must go back and re-code all the existing data, as well as collect and analyze more data until they are certain no new themes emerge. The adherence and awareness of traditional ramifications can be a sticking point for new researchers.

***Historical Contexts*:** Grounded theory developed from sociologists Glaser and Strauss [33] as a prescriptive method to develop theory based in observations from data. The process was developed in contrast to the dominant positivist scientific methodology of theory-hypothesis-test. Grounded theory allowed researchers to develop theory based on observations of social processes in context. Early descriptions of grounded theory describe more generally how to collecting data and theory

development [33] with more recent elaborations providing more specific steps, such as how to extract meaning from data [31].

***Common Assumptions in Application*:** McCall and Edwards [35] provide a detailed comparison of grounded theory core tenets between branches of grounded theory application. Though some pragmatic differences and epistemic differences exist, grounded theory branches share several components for theory development and validity: role of existing literature, sensitizing concepts, causality assumptions, role of the researcher, and quality criteria [35].

***Strengths & Weaknesses*:** Grounded theory has several branches with prescriptive texts on using grounded theory. This can be useful in that a set of guidelines is available for researchers new to grounded theory. The key strength of grounded theory lies in the discovery of new theory to explain social processes based on real life. Due to the nature of the theory developing directly from lived experiences data, ecological validity may be easier to demonstrate and more plausible than other theory generation methods. At the same time, grounded theory is susceptible to proposing theory which closely aligns with existing theory, therefore not creating a novel theoretical contribution to literature.

Conflict between branches of grounded theory can create confusion for researchers simply trying to conduct research. Conflicts between the main branches Straussian/Pragmatic and Glaserian [32], [36], constructivist [31], [37], and critical realist (i.e., [38]) are based in differences in data analysis processes and procedures (Straussian vs. Glaserian) and epistemology (positivist, constructivist, and critical realist) which can have important implications for researchers. Understanding each of these approaches may not be necessary for many new grounded theory researchers but choosing one process and staying in methodological alignment is necessary for consistency in data collection, coding, interpretation, and trustworthiness in the resulting theory.

***Examples*:** Faber et al. [39] used a constructivist grounded theory approach to develop a theoretical model of researcher identity and epistemic thinking in undergraduate research experiences. The manuscript identifies the process of moving from interviews to model construction based in grounded theory.

Useful methods texts and resources for thematic analysis methods:

[36] K. L. Rieger, "Discriminating among grounded theory approaches," *Nursing Inquiry*, vol. 26, *no. 1. Blackwell Publishing Ltd, 01-Jan-2019.*

[34] K. Charmaz, Constructing Grounded Theory: A Practical Guide through Qualitative Analysis. Thousand Oaks, Calif: Sage Publications, 2006.

Summary

Table 1 includes a summary of the main distinctions between content analysis, thematic analysis, and grounded theory. Pivoting researchers should read expansively on the analysis method they are interested in pursuing in preparation for the qualitative research project. The information presented here is intended as a beginning, not an end, to learning about qualitative analysis methods. Researchers should consider their epistemology and the types of research questions they would like to answer when evaluating analysis methods.

Table 1. Summary of the Main Distinctions Between Methods

Method Features	Content Analysis	Thematic Analysis	Grounded Theory
Research Question (answers these types of questions)	How often; What	Why; How	What (new) theory would explain X?
Use of Theory (how does theory inform analysis)	Frame research questions; What content should appear in data	Frame research questions and analysis	Assumption that no theory exists to explain X.
Data Collection (most common methods)	Online text (social media); Interviews; Document analysis	Interviews, Focus Groups, Narratives, Texts, Case Studies - any data with words that reflect peoples experiences.	Iterative, exhaustive, saturation Interview data
Analysis Methods (basic analysis process)	Coding - sorting into categories; Counting instances	Open coding based on theoretical basis; Abductive coding - recognition of new themes outside of the original theoretical basis; Saturation	Constant comparative method; Open coding - codes emerge from data; Axial coding - connections in open coding

Common Problems for New Qualitative Researchers

Qualitative researchers face a few common problems that bear mentioning, though this primer is not the place for an exhaustive conversation on these issues. While these common problems present challenges for all qualitative researchers, newer qualitative researchers may find them particularly daunting to overcome.

Trustworthiness. Trustworthiness refers to the idea that data, analysis, and interpretation of the data should be described in sufficient detail to reassure readers of the credibility of the research products. Qualitative researchers establish trustworthiness by demonstrating the precise, consistent, and exhaustive manner in which data was collected and analyzed [27]. Particularly relevant to the analysis method is the importance of recording the systematic process used in data analysis in detail [27]. In engineering education research, trustworthiness, often described as quality, is demonstrated through strategies and systems throughout the research process which provide basic validation and reliability for the data and interpretation presented [40]. There are several quality frameworks for both qualitative and interpretive research, as well as mixed methods research that have been proposed that are highly useful to researchers (e.g., see [40])

Theme Generation. Theme generation can be one of the most difficult aspects of high-quality qualitative research. Some themes may be easily identifiable in coded data; however, these themes may be too basic or general to add substantively to existing literature. A theme which is exactly derived from interview questions may not represent new information [26]. For example, if you ask about financial concerns in higher education because literature indicates that as a core concern, a theme of "financial concerns" likely will not add to the literature. However, you may be able to use this knowledge that finances are important as a guiding principle to identify themes within financial concerns specific to your research questions and population. Conversely, themes which become overly complex also may not contribute substantially to the existing literature. Qualitative themes which represent few or individual experiences likely will not contribute beyond description of lived experience and require extensive explanation to identify why the theme exists. Again,

these may point to other themes to investigate or develop based on additional evidence in answering research questions.

Thick Description. Qualitative research reporting requires descriptions of research participants, their lives, and situations to provide context to quoted text which enhances understanding of the participant's words [16]. Most qualitative research therefore includes quotes and excerpts of the interview that can range from a phrase to a few lines, to a whole paragraph, depending on the needs of the manuscript being produced. However, these quotes must be woven into the manuscript elegantly, and the burden is on the researcher/author to show through the presentation of the data the themes and the relationship between themes that they identified through the interpretive analysis really was indeed present in the data. One phrase that is often used is that of "thick descriptions," representing the idea that more in-depth contextualization of the quote will improve the reader's understanding as well as provide better support for the theme identified. While this concept sounds rather simple and reads elegantly in well-crafted qualitative research articles, the execution of thick description can be tricky for researchers at any level of expertise.

As a starting point, Ponterotto [41] provides a history and the attempts of researchers to define thick description. In essence, the thick description must provide social, emotional, interactional, and motivational contexts that allow the writer and reader to move from thick description to thick interpretation [41]. A common misstep for qualitative researchers happens when we simply describe the participant (i.e., male, white, engineering education postdoc) rather than describing and interpreting how these demographic descriptions help us understand a participant's comments.

Conclusion

The growth of interest in engineering education draws new researchers to the field who need assistance in developing and implementing their engineering education research ideas. This primer describes three common qualitative research methods, content analysis, thematic analysis, and grounded theory to provide basic information about each method, what types of research questions the method is optimal for answering, comparisons between methods, and potential pitfalls of the method. This primer is intended to be an accurate, concise, but high-level starting point for understanding methods, so that those newer to engineering education research or educational research can better understand the methods employed in various research articles, and when discussing or choosing methods to employ in a research design. Experienced researchers may find the primer useful when collaborating with newer or pivoting engineering education researchers to provide a concise overview reading for traditional engineering faculty to orient them in high-level qualitative methods conversations.

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