Novice-led paired thematic analysis: A method for conceptual change in engineering

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I. Abstract

This paper presents a revised analysis method for studies of students' conceptual understanding and conceptual change. The method emphasizes the roles of discussion and co-interpretation between two researchers with differing degrees of expertise in the content area under investigation. By organizing the analysis around the relative "novice's" learning, important insights can be gained into student reasoning. This method draws heavily from existing literature on conceptual change theories and methods. Increased use of our method could enrich engineering education research by encouraging more nuanced and informative characterizations of student conceptual understanding and the processes, triggers and obstacles of conceptual change.

II. Introduction

Research on students' conceptual understanding and conceptual change is largely dependent on qualitative methods including semi-structured interviews and think aloud protocols with thematic or inductive analysis. For example, Litzinger et al[1] used think-aloud protocols for strong and weak problem-solvers to identify technical errors common across the groups as well as differences between the groups in problem-solving processes. The application of methods such as these to student conceptual understanding is complicated by what is known in the teacher preparation literature as "expert blind spot" [2]. In this literature the phrase "expert blind spot" is used to refer to the broad-spread finding that teachers who know more about a subject matter are more likely to misunderstand or misrepresent student understanding in that realm[3]. It is likely that expert blind spot applies equally to conceptual change researchers, because an in-depth understanding of the subject matter is a basic requirement of conducting the research. Expertise in the subject matter is needed because students' understandings must be compared to more expert understandings in order to answer most of the research questions of interest to conceptual change researchers.

The purpose of this paper is to propose a new method of analysis that accounts for expert blind spot while making full use of experts' modes of thinking about the content matter. We call the method novice-led paired thematic analysis.

III. Background

The novice-led paired thematic analysis method was developed in the course of an ongoing project utilizing multiple data sets on student conceptual understanding of engineering concepts. Findings from this project are currently being developed and preliminary results are published [4, 5]. The purpose of the project is to begin to develop a theoretical approach to conceptual change in engineering, beginning with a cross-disciplinary analysis of student understanding of engineering concepts. In this use cross-disciplinary refers to the fact that some of the concepts we are investigating are important in multiple sub-disciplines of engineering (such as thermodynamics), as well as the fact that our analyses explicitly compare discipline-specific concepts (such as passage time in transportation engineering or binary encoding in computer engineering). Our current data set includes more than 200 student interviews.

Achieving our outcome, developing a cross-disciplinary theory for conceptual change, relies on our ability to develop strategies for data analysis that also cross disciplinary boundaries. Whereas studies conducted in single concept domains tend to have inherent commonalities, we faced different problems entirely in addition to different solution approaches. Therefore, the method reported here is the iterative result of more than a year of ongoing effort to collaboratively analyze data that spanned a range of difficult content areas. As such, the approach is still evolving so what we present here includes the core elements that have been the most important in improving our analysis of interviews for student conceptual understanding.

Although the method arose pragmatically from an effort to develop theory, we believe it is applicable to a broader range of studies. We argue that this approach is particularly beneficial to studies of student understanding including efforts in identifying misconceptions, validating measurement instruments, evaluating the effectiveness of interventions or investigating changes in students' conceptual understanding. Essentially it is useful for studies that examine novice perspectives.

IV. Novice-Led Paired Thematic Analysis

A. Overview

Novice-led paired thematic analysis is built on the idea that researchers working together can provide a richer, more rigorous and more theoretically sound analysis of student understanding of a content area when the analysis is guided by one researcher who is a relative novice in that content area. Both researchers code and analyze the data and meet frequently to discuss their analyses, but the meetings and general approach are managed by the content novice. The following sub-sections will provide more specific definitions of the key terms in the phrase "novice-led paired thematic analysis."

1. Novice

As implied by the name, in this application the "novice" has a lesser level of understanding. There is likely an ideal level of "novice," or at least some practical knowledge level range outside of which the benefits of not being an expert are overwhelmed by either too little or too much instruction. The most important feature of the novice-expert pair is a lack of shared assumptions: the novice needs to be sufficiently unfamiliar with the content area to have some difficulty interpreting the interview questions. In most cases, the interview questions used to characterize student understanding are directed toward either a specific concept or skill, and researchers familiar with the concept area are easily able to interpret what general concept is being examined. As an example, an interview about physics concepts could ask students to compare the acceleration of the projectile at different points in its trajectory. For most observers familiar with Newtonian physics, this question is clearly directed at the general idea that the acceleration of a projectile is constant as the only force acting on it is gravity. To a content novice, however, the question itself is difficult to interpret. A content novice might be asking, what is acceleration? or what, exactly, does it mean to refer to something as a "projectile" or a "trajectory?" Furthermore, a content novice might not share the common assumption that air resistance is to be ignored. This process of questioning the questions themselves is vital to the value of novice-led paired thematic analysis. In effect, the content-novice researcher is sensitizing the analysis to the elements of the interview that are unimportant or transparent to the expert interviewers, but could be central obstacles to the student interviewees. The novice provides additional potential explanations of student responses that must be considered before the students' understandings can be interpreted.

It is important to note that we define expertise relative to students' naïve understandings. The content "expert," then, would simply need to share assumptions about the content area with established content experts and have conceptual understanding that better aligns with accepted understandings than a student who may have just finished a first course in the topic area. In this case, the "expert" in our pair may not be considered an expert relative to a senior engineer or faculty-member who had taught the pertinent course over several years, but the "expert" should have a higher level of expertise and socialization in the content area than the novice. In other words, the "expert" may have developed a blindspot in his understanding of novice's statements. In this context, we argue that, in general, the introduction of such a difference is beneficial to conceptual change research when the novice's role is foregrounded.

This method depends on both researchers' being firmly situated in conceptual understanding and conceptual change research, including the most commonly applied interview, analysis and reporting practices as well as previous findings and theoretical underpinnings. In terms of conceptual change and understanding research, it is important that *neither* researcher is a novice.

2. Led

We have used several words to describe the role of the content-novice in leading the analysis. What we mean is that although both researchers must individually analyze the data, the collaboration is focused on the novice's analysis. At first this involves some instruction as the novice presents questions about the content and questions, but as discussed above, even this process is important to the rigor and value of the method. In our case "novice-led" referred to the fact that the content-novice would request the meeting frequency, and determine the general agenda of those meetings. Typically these agendas emphasized questions and discussion in the early stages, but then moved to simultaneously examining data. The novice might suggest a particular interview and then explain each line of coding. At the novice's request, the content-expert might explain their coding as well, but the key element is that the novice is carefully stewarding the development of their understanding of the content at the same time as developing an understanding of students' approach to that material.

This is a vitally important process, and can only really be managed by metacognition and self-analysis on the part of the content novice. While the content novice might be unfamiliar with the concepts in a particular area of engineering, it is important that they generally have expertise in the area of conceptual change research, so that the learning, research and collaboration processes can be appropriately managed.

3. Paired Thematic Analysis

Our definition of the term "thematic" borrows heavily from published methods[6-9]. In our synthesis, these sources describe an iterative cycle of analysis that slowly builds explanations or interpretations of the data from the data themselves. In general, there are there stages to this kind of analysis: labeling, description and interpretation. The process of labeling aims to develop many basic categories for the data. In the case of transcripts of interviews on student understanding, these categories could be the different stages of the interview, or labeling when students are responding to which interview question. "Description" requires slightly more interpretation as the researcher must name different sections of the data. In our case, for example, we labeled each student statement as either "correct" or "incorrect" in terms of how it would compare to an experts' answer to the same question. This was surprisingly difficult, and revealed that even apparently basic descriptions involve interpretations of the students' statements and intended meanings. Finally, the descriptions are grouped together based on the research questions and explanations or themes are constructed. In conceptual change research themes are typically groupings of concepts identified as more difficult for students, and sometimes includes potential reasons for that difficulty.

Although the second stages should not begin until some effort has been put into the first stage, these steps are not sequential; the "first" stage actually continues throughout the process as a "constant comparative"[10, 11] check on the relationship between the growing interpretations and the data themselves.

"Paired" thematic analysis means that both researchers are involved in all stages of the analysis, and that significant decisions are made collaboratively by both researchers. Once a coding scheme has been established one researcher may perform more of the analysis work. For example, after several meetings discussing one sub-set of interviews about mechanics of materials, we decided to split our analysis efforts and investigate different questions temporarily. It is key, however, that both questions were of interest to both researchers, and that all codings and other analysis documents were shared between both researchers. After a month of separate analysis, we reconvened and proceeded to co-analyze simultaneously again. If separate from the novice-led aspect, this approach of developing shared meanings would approximate researcher triangulation[12]. However, the novice-expert pairing puts the researchers in different positions with regard to data analysis and the shared meaning must be negotiated differently as described.

B. Process

After several cycles, we have found that novice-led paired thematic analysis generally involves three activities: instruction, parallel coding, and discussion. In our case, with two post-doctoral researchers devoting significant time to this effort, we were able to meet weekly for approximately two hours. Very roughly, then, we needed one hour each of instruction and discussion for every 30 hours of parallel coding. This estimate buries a great deal of variation and features specific to our project, and is only intended as a loose guide to the scale of time likely required for this method. In some cases for example, an entire weekly meeting was spent discussing a single code – in this case 2 hours of discussion were required for approximately one minute of parallel coding time.

As discussed above, the content-novice guides the discussions based on their developing knowledge of the content and student's understandings. However, these discussions must also be managed in terms of larger project goals. In our case of developing a theory for conceptual change, the goal of each discussion was to advance our collective ability to explain and describe students' statements in the interview data. In this light, spending two hours discussing a single statement was an appropriate (if necessarily rare) effort, in that a single example or counter-example can be very important in the development of a meaningful theory. In efforts to describe student reasoning, however, spending too much time on a single example would be wasteful as the goal is more oriented toward understanding of the students as a group.

1. Data Sharing

The mechanics of sharing data and analysis consumed a significant amount of time and effort early in the project, and would likely pose a challenge to any similar efforts. It is important to this method that both researchers have easy access to the other's analysis. It was surprisingly difficult to arrange this without requiring significant "maintenance" time from each researcher. The amount of data to be shared, the access and permissions of who it was shared with, and the managing of simultaneous editing were the most important features in dictating how we approached sharing, technologically. Finally, as these data originated from different projects in different universities, the IRB process was more complex than usual, and affected the logistics of sharing data in the form of anonymity, security and access considerations.

C. Narrative Example

Much of the data we have analyzed using this method was previously analyzed and published using more standard conceptual understanding analyses. These methods often incorporated more than one researcher, so a comparison between the findings can suggest some potential benefits of the novice-led paired thematic analysis method. This is not intended to be an objective, experimental comparison between methods, but rather an illustrative argument for the potential value of the method.

For example, a study was designed to investigate the role of problem set-up in students' understanding of axially loaded members in mechanics of materials. The data generated by this study was analyzed by a small team of researchers and has been reported on elsewhere[13, 14]. One of the findings from the original analysis was that some students' reasoning would change dramatically depending on the problem set-up. In response to one depiction these students would argue that a phenomenon (shear stress, for example) was occurring, but would argue that the same phenomenon did not occur when the same situation was depicted differently. Not every student's reasoning was affected in this way, but the finding remained interesting for the implications.

Under novice-led paired thematic analysis, the content-novice approached these same data without the ingrained core vocabulary that had informed the development of the interview protocol and the previous analysis. This sensitized his analysis to the assumptions and distinctions that are implicit in that vocabulary because he was currently engaged in the process of learning them and comparing his understandings to the other researcher's. Further analysis then investigated what distinctions students *did* make, and what those groupings were based on. In the case of mechanics of materials, these groupings were primarily based on direction and appearance on the loading (as suggested by the previous analysis). This process of investigating students' use of key terminology as a process of forming (or often disregarding) distinctions in phenomena was later applied to data from other content areas. The importance of students' distinctions was never fully investigated when the data was analyzed by experts, but students' distinctions became a focal point of the novice-led paired thematic analysis. These findings are to be reported in a forthcoming paper.

V. Discussion and Conclusion

A. Potential Benefits

We expect novice-led paired thematic analysis to have a number of benefits relative to individualized analysis by experts. The weekly meetings and collaboration force a close focus on the data itself because the other researcher has to be introduced to and convinced of any developing themes. The structure of the meetings focuses on codes, which are the analytical tools most closely related to the data. As implied above, a great deal of interpretation is somewhat hidden in researching students' conceptual understanding as researchers assume they know what students mean, or that students' statements accurately reflect their understanding of the concepts (rather than just the questions being asked, for example). The increased and structurally supported focus on the data is the greatest potential strength of this method.

Disagreements about coding, even when they arise to a misunderstanding of content on the part of the novice, force an ongoing attenuation of the theoretical framework guiding the research. We would expect this to be true even for projects not focused on developing theory, because challenging or defending codes forces the researchers to frequently and clearly communication about the goal of the research, and the methods that are assumed to be the best way of achieving those goals. Including communication in the process of analysis has the side benefit of better preparing that analysis for dissemination. Each finding is crafted as a conversation between researchers with different expertise, and is therefore more readily communicable.

B. Challenges

The greatest potential challenge is that this method requires a great deal of time from motivated and experienced researchers. While it would not be impossible for younger graduate students to work in this way, the relative expertise and confidence needed to engage in productive disagreements about analysis likely requires later-stage Ph.D. students, faculty or other expert researchers. Depending on the goal of the analysis, this process can take time without a great deal of visible output: a fully developed, rigorous and theoretically sound coding scheme is a significant accomplishment, but is difficult to list in a CV, annual activity report or tenure and promotion dossier.

A great deal of this method depends on social interactions between the co-researchers that are difficult to characterize and reproduce. For example, it was an important benefit in our particular case that the two primary researchers had different personal theories of conceptual change, and had read some of the same existing research, but also had each expanded into other areas unfamiliar to the other. It seems likely that certain disagreements – for example about what research paradigms are acceptable or appropriate in engineering education – would interfere with the application of this method. Similarly, too much agreement on research methods and goals would limit its true value.

A core question is how to develop the right balance of critically challenging the other's ideas, and respectfully allowing the ideas to develop despite disagreements or confusion. We believe that there are some key elements that outline the possible variations that would allow for the same potential benefits. For example, the development of our discussions was aided by our roles in the project as post-doctoral researchers. Our frequent meetings with the project PI's kept the project goals clear in our minds as the guiding purpose of our exchanges, but we were able to focus more on the research itself than would likely be possible for principle investigators who also have to manage other project personnel, budgets and reporting requirements. A second key feature was the definition of the analysis discussions and instruction as analysis tasks – they were all recorded and accounted for as analysis time, rather than meeting time. This is a subtle difference, and may serve mostly as a kind of motivational placebo, but the difference is then that meetings were not considered a place to present or share analysis, but a place where analysis is done. Therefore the outcomes of the time spent in the meetings were evaluated as outcomes of analysis – simply telling the other researcher an idea was not considered valuable unless that idea changed definition or became better supported (or contradicted) by the data. Finally, Korte's work in the philosophy of engineering education[15] has argued for the idea of "philosophizing" as a specific kind of discourse best suited to the sharing and development of ideas.

We do not want to suggest that our analysis method be adopted as a proscriptive recipe for "good" conceptual change research. Rather, we hope that the discussion of our method – including its drawbacks or impracticalities – leads to the development of existing methods and possibly the development of new ones as the field continues to progress.

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