AC 2010-823: USING THE EMERGENT METHODOLOGY OF DOMAIN ANALYSIS TO ANSWER COMPLEX RESEARCH QUESTIONS

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Using the Emergent Methodology of Domain Analysis to Answer Complex Research Questions

Abstract

As engineering education research matures, engineering education researchers seek to answer increasingly complex questions rooted in social situations, such as "What is engineering in various communities?" and "How does engineering work happen at various stages of professional development?"[1]. The desire to ask such questions leads the community to develop or incorporate diverse methods that help the community to answer the complex question. The purpose of this paper is to present to the engineering education community an introduction to domain analysis, an ethnographic method developed within anthropology[2] designed to answer these complex questions. Careful observation serves to identify productive routes to inquiry so as to move the researcher towards understanding relationships present within the social environment defined by the question. Because this methodology can call attention to both desirable and problematic relationships, results from this methodology can inform individual research agendas, program assessment, and policy creation by enabling researchers to construct a map of social situations.

Specifically, this methodology builds on the tradition of flexible design characterized by question asking, good listening, adaptiveness and flexibility, grasp of the issues, and lack of bias[2-3] and relies on anthropological techniques of domain analysis.[2, 4] We present domain analysis as an iterative four-step method:

1. Locate a social environment to observe.
2. Decide what evidence already present in that environment helps you answer your question.
3. Identify inter-relationships between the evidence.
4. Organize these relationships according to a question tree.

This paper explains these four steps within the context of engineering education research, with specific examples relating to our ongoing investigation of how engineering education researchers research gender. This paper is explicitly about our method; describing our data in detail is outside the scope of this paper. This research method provides important insights needed to design engineering education research agendas both at the individual and community level.

Introduction

As engineering education research matures, engineering education researchers seek to answer increasingly complex questions rooted in social situations. The desire to analyze social situations leads some engineering education researchers to pull in qualitative research methods from education,[5-6] marketing,[7] sociology,[8] history[9] and anthropology.[10-14] Qualitative methods from these disciplines provide researchers with an ability to explain situations in detail without necessarily having to make specific recommendations for future change. However, researchers who build on the tradition of applied anthropological research use their rich understanding of social situations to make specific recommendations for practice.[15] Applied anthropologists have investigated the culture of design firms,[10,16-17] global partnerships within high-tech industry,[18] and socialization of professional engineers[19] all with the goal of making recommendations for

practice. The purpose of this paper is to use techniques from applied anthropology to illustrate how domain analysis[2] can be used to advance research in engineering education.

As a methodology, domain analysis is well suited to answer complex questions. Complex questions feature "a community" as a crucial element of study, and reflect activities within a social environment. Different people can answer these very open-ended questions differently. Moreover, complex questions connect together with other questions. Indeed, the benefit to conducting research to answer complex questions lies in creating a thick description that can guide further inquiry.[2] Examples of complex questions present in the engineering education community include questions such as "How is design understood within engineering education?" and "Why is innovation valued by engineering?" Domain analysis is one useful technique for mapping cultural spaces to show order, organization, omissions, and potential places to make change.[2,4] As a *method*, domain analysis provides a way to arrange this observational data as a set of connected questions. The purpose of this paper is to describe our method *as a process* so that other researchers can see how the process unfolds. In particular, we focus our example of using this method to offer recommendations to inform others' future research regarding gender and engineering education.

Domain analysis is one of the many tools of naturalistic inquiry.[3] Broadly speaking, domain analysis can be understood as an iterative four-step method:[2, 4]

1. Locate a social environment to observe.
2. Decide what evidence already present in that environment helps you answer your question.
3. Identify inter-relationships between the evidence.
4. Organize these relationships according to a question tree.

This paper explains these four steps within the context of engineering education research, with specific examples relating to our ongoing investigation of how engineering education researchers research gender. Specifically, we approach our example from the perspective of applied anthropology where we seek to identify how researchers can make specific recommendations for practice. This research method provides important insights needed to design engineering education research agendas both at the individual and community level. It is hoped readers will gain insight as to how to investigate the complex questions in their individual research agendas.

1. Locate a social environment to observe

The identification of a social environment in which to situate the research study is a design choice. Because the utility of this method depends on appropriate site selection, we offer some suggestions as to how to select a suitable social environment. A social environment can be a literal site such as a particular laboratory or it can be a metaphorical site such as a loosely connected group of Internet blogs. To begin, social environments have three requisite components: place, actors, and activities.[2] However, the complex question already identifies both actors and activities. In considering the question of "How do engineering education researchers research gender?" we asked a question that had "engineering education researchers" as the actors and "research gender" as the activities. The social environment we choose to answer this question must include both engineering education researchers and people researching gender. However, a researcher has many options when it comes to deciding on a place to situate the

inquiry. In choosing a social situation, some researchers may find it helpful to make a list of everywhere they expect to see the targeted actors engaging in the specified activity. For instance, engineering education researchers who research gender might gather at a particular conference, work within certain research groups, or publish in particular journals.

The choice of an appropriate place shapes the subsequent inquiry. Researchers should think deeply and meaningfully about the location of their observations. Spradley[2] recommends considering six factors when choosing a social situation: simplicity, accessibility, unobtrusiveness, permissions, recurrence, and participation.

Table 1: Critical Factors Influencing Choice of a Social Situation

Criterion	Definition	Why It Matters
Simplicity	The scope of your investigation of a single situation	Naturalistic inquiry is unbounded, people move in and out of social situations according to complex networks
Accessibility	Ease of entry, ability to record observations	IRB protocols, industrial competitive advantage
Unobtrusiveness	Avoid calling attention to yourself	Social situations morph depending on people present
Permissions	Gatekeepers of the environment	Some entries can be quite limited owing to features of the site
Recurrence	Frequency of the activities you want to see	Detailed information requires many observations to validate analysis
Participation	Entering into the cultural environment	Opportunities to make richer observations by participating in the situation you are observing

The first factor, *simplicity*, involves a clear understand of why you want to conduct the study from the outset. Another way of thinking about *simplicity* is asking the question "What is the *easiest* way to get at the type of information I need to gather?" Deciding what you need requires a deep, working knowledge of your research question. Considering how your question might connect with other questions of interest within relevant research communities also helps you decide if you are asking a good question. Considering both the *easiest* and *relevant* social situations offer a means of defining the scope of your inquiry. We chose to situate our inquiry of understanding how engineering education researchers research gender in the *Journal of Engineering Education* because this journal seeks to catalyze rigorous engineering education research and is readily available to us as researchers.

Ideal *simplicity* of a situation involves a single place. This definition of simplicity can free a researcher from undue concern about trying to capture every facet of inquiry in an open system. Inherently, human experiences and interactions are unbounded; what engineers call an open system, other researchers would call naturalistic, or real-world, inquiry. A researcher must spend considerable time and effort putting a boundary around the "place" of their inquiry, much akin to the need to scope engineering problems.

A place can only provide productive inquiry if the researcher has *access* to the place. A researcher with access can enter the environment and record observations. When a researcher enters an environment, he or she should be *unobtrusive* so as to not interfere unduly with the social interactions present. Many, but not all, social situations require permission to collect observational data. For instance, one does not need permission to conduct observations of adults' public behavior in a public library. However, if one wanted to conduct observations in an elementary school library, then one would likely need the permission of the principal and librarian to be present. With limited-entry and restricted-entry scenarios, a researcher has to gain access to a social situation from a gatekeeper; conversely, free-entry scenarios do not necessarily require *permission* for access.

Recurrence speaks to the expected frequency of the desired activity. Places should be selected for a likely high frequency of the desired activity so the researcher can gather enough data to discern underlying patterns. Moreover, the researcher must enter the environment in a way that allows the researcher to be present in a socially relevant manner without compromising his or her ability to make observations. The available roles for the researcher as a participant inform what information can be gathered through *participation*. Researchers can carefully navigate their entry to an environment to enable them to participate fully. To minimize being obtrusive, researchers should navigate their role in the social space before they enter.[2,4] For instance, entering into a workplace as a design engineering intern allows a researcher to be a participant observer, without being unduly obtrusive.[17]

It is important to remember that, to use this research method effectively to explore complex research questions, one must realize that the choice of place represents a crucial piece of research design. The researchers must think about their purpose in order to inform the design of this research. Moreover, not all data carries the same ease of collection. Without careful consideration of the inquiry's purpose, researchers can easily create significant additional work for themselves that adds no value to the results. One key way to add value to the study is to consider relevance to a broader community, whether that community is a research community or a community of practice. Furthermore, knowing the audience allows researchers to generate logically connected questions. The choice of place directly informs the scope and relevance of the study; choose wisely.

2. Decide what evidence already present in that environment helps you answer your question.

Suppose researchers attended a meeting to explore engineers conducting engineering design work. Clues such as drawings, client presence, discussions about various functions of the device, and a high amount of technical language use could provide evidence that engineering design work is actually occurring in that meeting. This step involves deciding what may serve as evidence that the desired activity is occurring. At one level, some manifestations of the activity occurring will be immediately obvious; at another level, the logic of these manifestations remains obscured by the researcher's tacit knowledge. For instance, researchers who explore engineering design might make a number of assumptions if they also teach engineering design. Spradley[2] proposes that researchers begin with "grand-tour" observations, much akin to being a guest visiting someone's home. "Grand-tour" observations allow a researcher to orient to the

space, identify obvious manifestations of the activity, and locate places warranting further investigation. Generally speaking, these observations occur along nine dimensions, described in Table 2: space, actor, activity, object, act, event, time, goal and feeling[2].

Table 2: Nine Dimensions of Observations in a Social Space

Dimension	Description	Example of a design review event
Space	The physical place or places	A small conference room with a whiteboard
Actor	The people involved	2 professors, 5 students
Activity	A set of related acts that people do	Present a Powerpoint presentation, Review various journals created by students
Object	The physical things present	Table, chairs, computer, notebooks, pens
Act	Single actions that people do	Advance a slide, ask a question
Event	A set of related activities that people carry out	Design review
Time	The sequencing that takes place over time	Senior professor talks (2 min), students takes turn each speaking for 2 minutes, other professor interjects questions during talk
Goal	The things people are trying to accomplish	Convey details of a design, articulate a design to client, respond to feedback
Feeling	The emotions felt and expressed	Exhaustion, elation, frustration, joy, defeat

Depending on the scope of the inquiry, a researcher may only be interested in a subset of these dimensions. For instance, in considering how engineering education researchers research gender, we focused on the actors, activities, goals, acts and time. Some dimensions, such as objects and feelings, did not feature strongly enough in our social space of the *Journal of Engineering Education* to observe directly through the text. Depending on their research question, researchers working in a classroom or within a research group may want to pay more attention to the objects present and the feelings expressed.

"Grand-tour" observations provide a starting point for inquiry. For instance, in examining how engineering education researchers research gender in the *Journal of Engineering Education*, we first needed to identify the presence of research about gender. If researchers used gendered vocabulary ("gender," "women," "men") in the title of their article, then we anticipated the researchers having a GOAL of researching gender. Similarly, some articles contained biographies for researchers saying they had a gendered research specialty, suggesting this researcher considered himself or herself as an ACTOR in gendered research. Key OBJECTS emerged as people cited key works of gendered theories of learning such as *Women's Ways of Knowing*.[20] Moreover, particular use of "masculine" and "feminine" represented a particular ACT that indicated the presence of gendered research.

Moreover, the interactions between the respective observation dimensions inform subsequent inquiry-driven questions. For instance, in the context of this research team's focus on how

engineering education researchers do research on gender, do particular researchers (ACTORS) focus on specific methodologies (ACTIVITIES)? Do researchers cite differing motivations (GOALS) over the period of many years (TIME)?

3. Identify inter-relationships between the evidence

Before digging further too deeply into inquiry-driven questions, a researcher should begin to consider inter-relationships between the evidence gathered. Observational data can provide a rich and abundant source to answer many complex research questions. However, the challenge remains to organize seemingly disconnected observations into a coherent whole. Establishing inter-relationships helps researchers group observations in category groups by articulating a connecting question and describing interactions between dimensions. Every relationship implies a question; however, in the iterative nature of this methodology, researchers might identify either the relationship or the question first. For instance, researchers might see well-kept design notebooks and a syllabus where professors require well-kept design notebooks for a substantial portion of the grade before they ask the question "Why do students keep well-kept design notebooks?"[21] However, further observations might reveal other causal relationships making the question itself necessary.

Spradley[2] identifies 9 types of semantic relationships used to organize various inter-relationships. Moreover, these relationships should nest together categorically.

Table 3: Nine types of semantic relationships

Semantic Relationship	Generic Form	Examples
Strict Inclusion	X is a kind of Y	Freshmen students are a kind of population investigated by engineering education researchers,
Spatial	X is a part of Y	A lab bench is part of a laboratory.
Cause-effect	X is the result of Y	Delivering a portion of a presentation is a result of peer selection.
Rationale	X is a reason for doing Y	The problem of underrepresentation is a reason for doing gendered research in engineering education.
Location-for-action	X is a place for doing Y	A conference is a place for speaking on research.
Function	X is used for Y	Late evenings are used for assembling presentations.
Means-End	X is a way to do Y	Focus groups are a way to gather information about students' experiences.
Sequence	X is a step in Y	Creating a prototype is a step in the design process.
Attribution	X is a characteristic of Y	Authority is a characteristic of the client.

As examples, below we list some of the inter-relationships that emerged from our analysis of engineering education researchers conducting research around gender.

- Research REQUIRES a researcher, research questions, research methodology, and broader motivating context.
- Sex, masculine, feminine, boy, girl, gender, male, female, men, women ARE ALL gendered vocabulary
- Underrepresentation is a REASON TO DO research around gender.

4. Organize these relationships according to a question tree.

Organizing these relationships according to a question tree helps other people follow your logic. (An example of a generic question tree is in Table 4.) Moreover, these question trees make visible which questions you asked and what question trails you followed, not only to you as a researcher but also to your audience. By extension they offer insight into questions you did not ask. All questions should connect back to the original question, but provide specific explorations relevant to the topic.

Table 4: Generic Question Tree

<table>
<tr><td colspan="5">Complex Question</td></tr>
<tr><td colspan="2">Grand Tour</td><td>Grand Tour</td><td colspan="2">Grand Tour</td></tr>
<tr><td>Inter-relationship Question</td><td>Inter-relationship Question</td><td>Inter-relationship Question</td><td>Inter-relationship Question</td><td>Inter-relationship Question</td></tr>
<tr><td>Deepening Question</td><td>Deepening Question</td><td></td><td></td><td>Deepening Question</td></tr>
</table>

For example, consider one branch of a question tree on our example of gender research:

- Complex question: How do engineering education researchers research gender?
- Grand tour question: Who focuses on gender as a research area (actors)?
- Inter-relationship question: What reasons do they provide to motivate their research (goals, rationale)?
- Deepening question: What sources, if any, are cited to validate these reasons (object, function)?

Please note that ethnographic inquiry requires a researcher to suspend judgment during data collection to consider the observations in context in order to keep a holistic view. In analyzing results, a researcher might identify features as problematic or limiting. The presence of problematic or limiting features can identify future action steps within the broader research community. We hope to release specific recommendations for improving how engineering education researchers research gender that may include, but are not limited to, the following:

- Identifying other theoretically appropriate reasons to conduct research around gender that do not hinge solely on threats of a diminishing technically-trained workforce;
- Exploring how engineering and engineers "perform" masculinities and femininities;
- Broadening the sense of holistic, integrated engineering education to include considerations for all forms of diversity; and
- Translating and testing theories of gender from other disciplines within the specific engineering context.

The real strengths of this method for guiding engineering education research lie in the method's ability to represent positive and negative attributes of the cultural space that permit and block the desired activity. Connecting the question tree to a specific goal or challenging problem can lead towards intervention. A researcher's perception of a challenging problem may be the motive for using this methodology to explore a complex question. For instance, the complex question asked could be expressed in the form of a challenging problem of, "What is required for engineering education researchers to research gender?" This problem points to the issue of researchers, ability of those researchers to secure funding in the articulated goals of a research community, access to diverse populations, and the need to articulate research within a theoretical framework or a methodology designed to help create theoretical frameworks.

Some concluding thoughts

Through this paper, we have shared a research method that can guide the work of researchers and a broader research community. We are using this method to investigate questions of how engineering education researchers research gender; we look forward to sharing our results in the near future. However, as engineering education researchers seek to develop research agendas shaped by complex questions, this research methodology provides engineering education researchers a means to investigate complex questions so as to craft future research agendas both at the individual and community level.

We close with some final practical advice, rooted in our experiences of working with this methodology. At all points, the process depends on iterative, open-ended design. The quality and utility of this form of inquiry stems directly from an articulated understanding of a relevant social situation in which to conduct the inquiry. Scale matters. Researchers should be willing to revisit definitions, relationships, and connectedness. Definitions emerge from observations as the method depends on continual inquiry. Researchers should ask logically connected questions because the questions themselves matter. This methodology provides a way to map a cultural space through detailed relationships between questions and observations. It is essential to keep track of how the questions relate. Moreover, questions can lead the researcher to go into a great deal of specificity, and researchers should be advised to choose their depth of inquiry carefully because the inquiry can easily grow beyond the designed intent, making it difficult to leverage specific and relevant recommendations.

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