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Work in Progress: Using Ego Network Analysis to Analyze How Engineering Education Researchers Construct Mixed Methods Designs

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Abstract

This work-in-progress paper introduces an emerging method for conducting a systematic methodological review of mixed methods publications, which we apply to engineering education research. Although a smattering of methodological reviews exists, studies to understand how researchers approach integration, the central feature of mixed methods designs, in engineering education are scarce. By applying a network-analytic model to visualize design procedures, specifically ego network analysis, and typologies of integration strategies, we can map the mechanisms by which engineering education researchers perform integration in their studies. From these networks, ego networks of integration strategies can be generated that can inform scholars inside and outside the field how previous studies have combined different methods. The direct impact on the field is a comprehensive examination of integrative procedures in engineering education research adaptable to various mixed methods designs.

Introduction

Methodological reviews of mixed methods research in engineering education are scarce. Previous work by Crede and Borrego [1] and Kajfez and Creamer [2] examined mixed methods publications across popular venues in the field like the *Journal of Engineering Education* and ASEE conference proceedings. Crede and Borrego [1] focused primarily on the issue of mixing and priority (i.e., quantitative or qualitative dominance) using thematic analysis using criteria established by Creswell and Plano Clark [3], whereas Kajfez and Creamer [2] focused on evaluating a selection of 16 articles using Creamer's Mixed Methods Evaluation Rubric. Both reviews focused on the concept of mixing, which is the fundamental quality of mixed methods research used synonymously with the term *integration* – the point where qualitative and quantitative procedures interface with one another [4,5].

Integration is so central to mixed methods research that it is perhaps unsurprising that the editors of the flagship methodological journal, *Journal of Mixed Methods Research*, posed the "integration challenge" [6, p. 115]. The idea behind the integration challenge is to push researchers to interweave qualitative and quantitative approaches purposefully to achieve a value-add or new whole in novel ways, moving beyond barriers to mixing identified by Bryman [7] in his classic article. Since the days when integration was called "undertheorized and understudied" [8, p. 125], theoretical manuscripts and books have explicated the myriad analytical techniques for mixing [e.g., 4, 5, 9, 10, 11] – including dissenting perspectives on whether integration is the optimal outcome of a mixed methods study [12]. Integration occurs along the dimensions of the so-called integration trilogy, which involves the methodological dimension (i.e., the system of methods at the methodological level), the method dimension (e.g., data collection and analytical procedures), and the philosophical dimension (e.g., theoretical underpinnings, ontology, epistemology) [13]. A recent review [14] highlighted purposefully selected exemplars of integration addressing the integration challenge [6] in engineering education publication venues; however, the review was not systematic, leaving a broader synthesis of contemporary approaches to integration in engineering education unexplored.

To conduct such a synthesis, we can leverage a tool for visually synthesizing the current state of mixed methods research in the discipline, procedural diagrams. Procedural diagrams are visualizations that describe the sequencing and timing of data collection and analytical procedures [4, 11]. Beyond providing a picture of the researchers' processes, these diagrams help readers identify the core designs inherent in the authors' research plan and how different data strands are "linked." By examining these "links," we can understand common connections between existing quantitative and qualitative methods and assess how the various research approaches are integrated – specifically in the methods dimension in the integration trilogy.

Research Aims

This work-in-progress paper aims to demonstrate a technique for understanding how researchers use integration strategies to construct mixed methods designs, focusing specifically on engineering education publications in this instance. Previous reviews by Crede and Borrego [1], Kajfez and Creamer [2], and Reeping and Edwards [14] evidence how engineering education researchers have embraced elements of what embodies mixed methods research. However, little work has examined *how* engineering education researchers integrate in their designs. We can often ascertain the *how* behind authors' integration processes through procedural diagrams, but these are infrequently used in prominent publication venues like the *Journal of Engineering Education* and the *European Journal of Engineering Education* [14]. Despite such omissions, the analytical strategy presented in this work-in-progress paper advances how a researcher in any discipline, whether seeking to examine the state of a field, set of journals or publication venues, or a certain body of research within a field, can construct a dataset of procedural diagrams to examine the corpus' methodological landscape.

The Method, an Ego-Network Systematic Methodological Review

The premise of the method described in this paper draws from work by Ring and Frohlich [15], which examined mixed methods research designs in mindfulness research. Their insight was to consider a research design as a network, where each procedure in the design was a node (or vertex), and the arrows connecting the procedures (called edges) defined the sequence followed by the authors. For the purposes of this paper, we will call these *procedural diagram networks*. With enough manuscripts (i.e., at the very least two with a common vertex), one could construct the *ego network* of a particular method to see how authors in the corpus paired other methods with it. The ego network is a subset of the vertices in the network, formed by considering one vertex – the ego – plus any other vertices to which it is connected – alters – and the connections *between the alters*. An example of an ego network is shown in Figure 1.

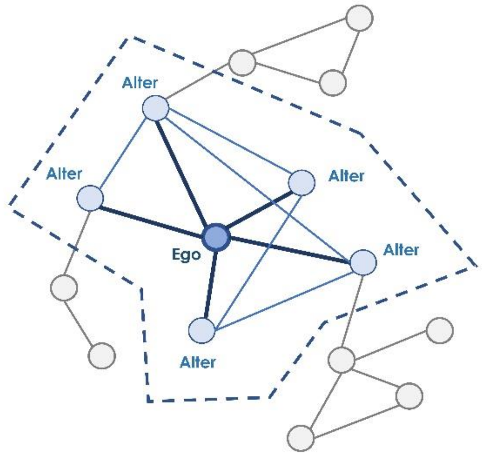

Figure 1. An ego network (blue) composed of an ego and its immediate connections, alters

Data Collection and Preparation

Preparing the data involved four steps: (1) collecting relevant papers, (2) documenting design procedures from the selected manuscripts, (3) coding the content, and (4) defining the sequencing of design procedures. In this case, the publication venues chosen were the *Journal of Engineering Education* (*n* = 17), the *European Journal of Engineering Education* (*n* = 20), and the ASEE Annual Conference proceedings (*n* = TBD). The search for manuscripts was conducted using Creswell and Plano Clark's [4] recommended strings: "mixed method*" OR mixed-method* OR "qualitative AND qualitative" between 2014 and 2021 to avoid overlap with previous reviews. From there, each manuscript was reviewed to verify if the research design was indeed mixed methods and if the manuscript was empirical, not a theoretical discussion. Manuscripts meeting both criteria were included in the review. Aside from critiques about the lack of substantive integration in the design, the research quality of the individual design phases was not vital to this method. Thus, screening for quality was not necessary.

Next, each manuscript was read to extract the details of the research design. Each data collection (e.g., focus group, interview, survey) and analytical procedure (e.g., t-test, emotion coding, descriptive statistics) described in the manuscript was assigned a letter and procedure type (QUAN, QUAL, MIXED). The sampling strategy and sample size (if the procedure was data collection), an excerpt from the manuscript to describe the procedure, and any alternative labels that could explain the procedure in more detail were also extracted as additional information.

As the data were entered into a spreadsheet, the researcher applied a combination of typologies for describing mixed methods integration techniques to categorize procedures that were indicative of integration. Authors do not often use terminology from the mixed methods literature, so it was vital to juxtapose the text with a typology for integration. First, an enduring set of descriptors for individual procedures from Fetters et al. [16] include building, connecting, and merging (Table 1). However, a proliferation of integration strategies could be reasonably nested under the three terms, complicating the classification process. For example, a joint display – i.e., a visualization that juxtaposes quantitative and qualitative data [17,18] – necessarily involves the integration strategy, *merging*. To capture more specific mixing techniques, Creamer [5] presents five strategies used during analysis: blending across strands, creating a blended variable, converting (or data transformation), extreme case sampling, and cross-case comparison.

Table 1: Broad Integration Techniques from the Mixed Methods Literature

Approach	Description
Connecting	One dataset is related to another through the sampling design; e.g., participants are chosen for a focus group based on quantitative analyses from a questionnaire.
Building	One dataset is used to inform the data collection approach of another dataset; e.g., themes from a qualitative analysis are used to create items for an instrument to measure a certain construct.
Merging	Combining two or more datasets for the purpose of analysis.

To remedy the potential for multiple labels in this application, each mixed procedure was given a primary label based on the broader terms in Fetters et al. [16] within Table 1. Any secondary labels that expanded on the specific integration technique used to describe the procedure were recorded in a separate column using the labels from Creamer [5].

Finally, to make the connections between the procedures, a separate text file for each manuscript was created to define the connections in the procedural diagram networks. The researcher closely read the manuscripts and created a new line in the text file to document the order of the procedures in the spreadsheet, as described by the authors. Arrows were connected to vertices earlier in the network if the authors engaged in multiple iterations of the same procedure. Example data to clarify the precise organization of the data is given in Appendix A.

Analyzing the Data

The data were analyzed in R [19] using the igraph package [20]. The networks were aggregated into one large network such that the ego network could be constructed for specific procedures. The "ego" function in the igraph package was used to select a procedure as the ego and build the ego network from it. The eligible procedures for the ego network were expanded using the "order" parameter in the igraph "ego" function. For an ego network of order n, procedures n links away from the ego were included in the network. From an nth order ego network, nodes can be grouped to explore collections of procedures and visualize the scope of methods used as part of an integration strategy – including other integration strategies – and further coded for mixed methods purposes [e.g., 21].

Selected Results

An example ego network from the data is shown in Figure 2. The integration strategy, *building*, served as the ego of the second-order ego network. We can make a few observations that uncover different modes of integration and priority, even in this small network that intersects five studies from the *Journal of Engineering Education*. First, despite *building* not necessarily implying the creation of an instrument as described in Table 1, both outcomes of *building* involved creating a questionnaire or instrument. However, they were proceeded by different types of coding – one was deductive, whereas the other open/axial coding was more indicative of an inductive, grounded theory design. Moreover, *building* was associated with the *merging* strategy, where axial and open codes were combined with cluster analysis results from the questionnaire, showing how multiple integration strategies can be used in sequence. We can also comment on the order in which authors implemented their procedures. In this network, all paths into the ego are QUAL, and all leaving paths are QUAL, suggesting sequential explanatory design types (QUAL followed by QUAN) are most often associated with the *building* strategy in this article set. Observations about modes of integration and priority can be made for other ego networks as well.

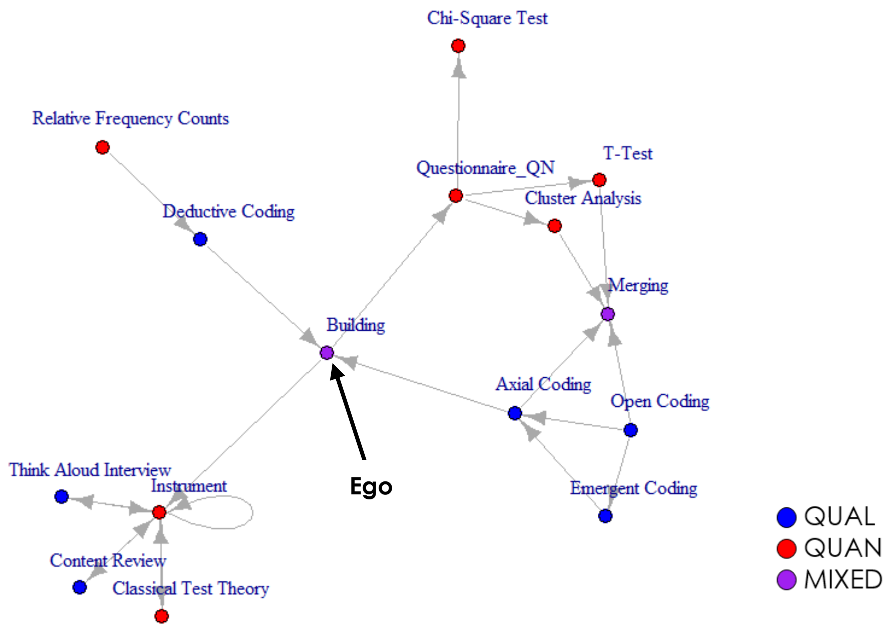

Figure 2. A second-order ego network for the integration strategy *building*

Conclusion

This work-in-progress paper argues that framing a methodological review from the perspective of the integrative strategies and the associated procedures can uncover how authors in a field like engineering education approach the cornerstone of mixed methods research designs, integration. The next step involves incorporating papers from ASEE PEER, exploring different types of integration strategies as labels, and making the networks broadly available to the community.

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Appendix A: Example Data and Preparation for Analysis

File 1: Spreadsheet (.csv) outlining design procedures. Table A1 showcases the absolute minimum data needed to conduct the analyses described in this paper. The data format is *panel*, which is associated with longitudinal data. In a panel data format, each row is not a unique individual – or manuscript in this case. Instead, the first column identifies the manuscript, Litchfield et al. (2015), and each row is another observation of the same manuscript, which are the research procedures in Litchfield et al. (2015). Each distinct method in the research design is given a label, abbreviated by a letter, and is assigned a type: QUAN, QUAL, or MIXED. Additional columns can be added to describe the sample size, another name for a method, excerpts from the manuscript, or any other relevant labels chosen by the researcher.

Table A1: Example of data organization from extracted manuscript

Filename	Procedure_Label	Procedure	Procedure_Type
Litchfield_et_al_2015_JEE	A	Interviews	QUAL
Litchfield_et_al_2015_JEE	B	Focus Groups	QUAL
Litchfield_et_al_2015_JEE	C	Descriptive Coding	QUAL
Litchfield_et_al_2015_JEE	D	Data Transformation	MIXED
Litchfield_et_al_2015_JEE	E	Relative Frequency Counts	QUAN
Litchfield_et_al_2015_JEE	F	Deductive Coding	QUAL
Litchfield_et_al_2015_JEE	G	Building	MIXED
Litchfield_et_al_2015_JEE	H	Questionnaire_QN	QUAN
Litchfield_et_al_2015_JEE	I	Chi-Square Test	QUAN
Litchfield_et_al_2015_JEE	J	T-Test	QUAN
Litchfield_et_al_2015_JEE	K	Multiple Logisitic Regression	QUAN

File 2: File (.txt) describing connections between procedures. If the number of manuscripts is *n*, there will also be *n* .txt files explaining the relationships between the methods described in the manuscript. The file describes the order of the methods using the Procedure_Label column. Based on the manuscript's description of the design, make a .txt file where each line has the form: X Y, where the procedure Y follows procedure X. Figure A1 shows the .txt file for the example in Table A1 and the resulting procedural diagram network.

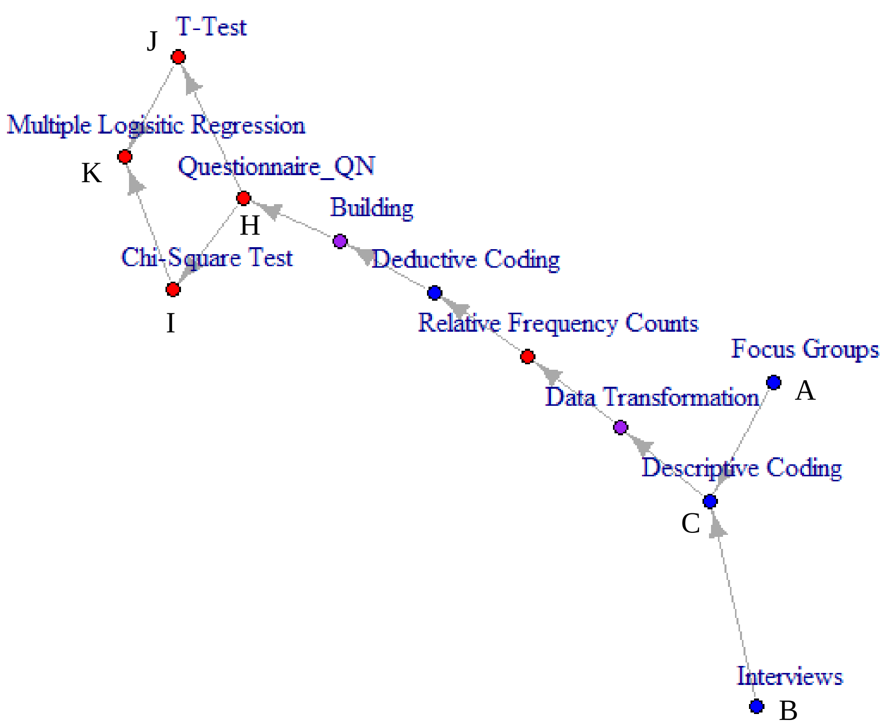
Note that not all procedures will be sequential. Some procedures may occur simultaneously, or there may be iterations in the design where a set of procedures repeat. In the case of the example in Table A1, the interviews (A) and focus groups (B) were conducted at the same time and coded deductively (C) after both data were collected. To represent this configuration in the .txt file, we would connect A to C and B to C, but there is no connection from A to B because A and B occur simultaneously. Similarly, the questionnaire (H) was followed by a chi-square test (I) and t-test (J), which concluded with multiple logistic regression (K). Therefore, the connections are H I and H J, followed by I K and J K. These configurations are highlighted in Figure A1 with the procedure's respective letter.

Creating the network. To create the procedural diagram network in R, the user can import the .txt file using *read.table* function as the variable *edges* and .csv file using *read.csv* as the variable *vertices.* The function *graph_from_data_frame* in the igraph package can be used like so:

```
procedural_diagram <- graph_from_data_frame(edges,
                                            directed=TRUE,
                                            vertices=vertices$Procedure_Label
                                           )
```

If desired, other details like procedure type or sample size can be added to the vertices using the *set_vertex_attr* function. For example, one could add the procedure type column from Table A1 to the procedural diagram network – which can be used to color code the vertices like in Figures 2 and A1. The function call will look like this:

```
procedural_diagram <- set_vertex_attr(graph = procedural_diagram,
                                      name = "type",
                                      index = V(procedural_diagram),
                                      value = vertices$Procedure_Type
                                     )
```



To	From
A	C
B	C
C	D
D	E
E	F
F	G
G	H
H	I
H	J
I	K
J	K

Figure A1. Example procedural diagram network and generating .txt file for example article