A Mapping Review of the Use of Frameworks in Engineering Education Research Grey Literature

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***Abstract*— In this paper we provide an overview of theoretical and conceptual frameworks used in engineering education research (EER). First, we define the considerations for how the terminology around frameworks is used and how they are applied in the discipline. Then, we conduct a mapping review of different theoretical and conceptual frameworks used in EER that have been identified from grey literature publications in the discipline. We specifically use grey literature for this analysis to explore how frameworks are being used beyond their representation in traditional venues such as journal or conference publications, which are often post-hoc. Given the growth of EER during the past decade, many of the novel ideas and frameworks are likely to be first discussed and available in these venues. Furthermore, within the grey literature we analyze, frameworks are likely to play a broader role, including guiding the research design. The grey literature we analyze includes NSF-funded proposals, and engineering education Ph.D. dissertations from US institutions over the past decade (2011-2021). We examined a total of 194 dissertations and 106 NSF proposal abstracts uncovered using a set of keywords, academic discipline, and research areas. Our analysis approach utilizes and expands on existing categorizations, such as the Engineering Education Research Taxonomy and other categorical approaches within both the engineering education field and adjacent STEM and technology-related disciplines. Finally, we recognize the limitation of examining research situated only in the US but hopefully this study provides a roadmap to extend the analysis across other geographical areas with EER presence.**

Keywords—frameworks, engineering education research, grey literature, empirical study, dissertations, NSF proposals

I. Introduction

A defining characteristic of the development of any academic field or discipline is the application of well recognized theories and methods, and field-driven theoretical and methodological innovation. Within interdisciplinary fields such as engineering education research (EER), a range of theories and methods are applied depending on the research question being investigated or hypothesis being tested. In addition, the leanings of a researchers, whether positivist, post-positivist, or interpretive, further shape the use of theories and methods.

One common element across research studies, regardless of the epistemological and empirical preferences of a researcher is the use of frameworks. Similar to other interdisciplinary fields, the use of frameworks is important in EER as they shape, define, and ground the study focus, methods, and contextual considerations. Since EER is positioned in the cross-section of education, psychology, sociology, computing, and engineering research, the frameworks used in the field represent a breadth of disciplines. This gives the field diversity and vitality, and the ability to undertake novel research. But the one downside of this multiplicity is that it can make exploring and selecting potential frameworks for researchers new to the field of EER a daunting task. The use of frameworks is made ever more difficult within EER as the field includes many researchers and practitioners that have engineering disciplinary backgrounds and training. They may teach in specific engineering fields and research the educational settings where students learn and engage with discipline-specific content.

One source for understanding the development of knowledge within any field, including their use of frameworks, is to examine the *grey literature* in the field. Grey literature refers to information sources within the field that do not appear in traditional venues such as conferences and journals and include outputs such as dissertation, research proposals, and technical reports, and, increasingly, online repositories and archives such as arXiv [1]. One criteria that differentiates grey literature from other forms of information sources, often referred to as grey information, is that even though they might not be traditionally published, they are still produced for consumption by a committee of peers or experts in some way. Dissertations are vetted by a committee of experts, research proposals by a committee of experts who might be peers, and even technical reports, even though they might be produced for commercial purposes, are still reviewed by a committee, or in the case of newsletter, are targeted for consumption by those knowledgeable in the field [2]. In the study presented in this paper, we utilize two well-recognized genres of grey literature, dissertations, and research proposals.

II. Background

As discussed earlier, EER is positioned in the cross-section of education, psychology, sociology, computing, and engineering research, consequently, frameworks used in the field represent a breadth of disciplines. Communicating and sharing knowledge in these disciplines is typically framed through interconnected ideas that help readers interpret, contextualize, and understand research and practice in the discipline. Frameworks that shape these interconnected ideas are important in EER to formulate, define, and ground the study focus, methods, and contextual considerations. Concepts, constructs, and theory are other structures that help scholars organize and interpret research and scholarship. For instance, the utility of using theory is to facilitate a shared understanding of how research and scholarship are interpreted. However, scholars may use these abstractions related to theory differently.

The engineering education community realizes the diverse and interdisciplinary nature of the research conducted in the field and developed an approach to leverage this nature for cross-fertilization and creativity [3]. The EER Taxonomy was created for researchers, journal editors, newcomers to the field, and anyone engaging with engineering education research and scholarship to provide an organizational tool and standardized terminology for engineering education research. The taxonomy (Version 1.3 September 17, 2021) consists of 14 sections, each comprising multiple terms. *"Section 13 – Theoretical Frameworks"* influenced how we went about conducting this process and informed us of what domains the theories may be coming from.

Underpinning is a term adopted from Passey [3] to include terminology related to how theory is identified in the literature, such as models, frameworks, and theories. We found that in reviewing EER theory, the term (and related terms) "underpinnings", as defined by [3], allowed us to review the broad nature of the EER grey literature. Passey outlines and defines four specific forms of underpinnings which inform our definitions of the terminology for this paper. These four forms are "model, conceptual framework, theoretical framework, and theory [3]. The definitions of these terms are presented in Table I.

TABLE I. Passey's Four Forms of Underpinnings for research [1].

Term	**Definition**
Model	A model holds for a given case or stated population, arising from context-specific research, often indicating main features of influence or contribution.
Conceptual Framework	A conceptual framework tends to be more flexible and descriptive, as it usually identifies factors or criteria that have influence on a particular field within the more major features, which might be, for example, social learning, discovery learning, or experiential learning.
Theoretical Framework	A theoretical framework arises from outcomes beyond a single study, based on one or more theories, which might be, for example, social constructivism, constructionism, or behaviorism.
Theory	A theory considers a broader and deeper concern or context, suggesting the detail of what might be more general, beyond one or a number of contexts.

This paper explores the underpinnings (theories, frameworks, models, or constructs) found in EER grey literature, thus identifying what is already being used, what is becoming more commonly used, and the potential opportunities for extending the use of these underpinnings in the future. We initially used the Taxonomy as a classification approach for the various theories identified in the NSF Proposals and the dissertations. Our specific research question regarding the underpinnings was:

What underpinnings do U.S. Engineering Education grey literature sources commonly and explicitly cite?

The following section describes the study methods and data collected, i.e., the "grey literature." Although publicly available online, both proposals and dissertations are often considered "grey literature" [4], and these types of publications are not extensively cited in Engineering Education Research. However, these sources are essential mileposts to understanding research and topic trends within the domain as they are milestones for research and scholarship. Doctoral dissertations represent the end point of a graduate student's work and the starting point of their post-student career. As a result of the expected contribution of the dissertation, these artifacts often include significant sections of theories, constructs, frameworks, and models. On the other hand, NSF Proposals serve as a next step in continuing research on a topic and focusing on the novel application of the theoretical and conceptual work. They often use developed frameworks in an applied manner. Proposals also outline funding priorities within the domain. They are an illustrative publication source to study because they generally represent the direction funded research in EER is moving.

III. Study Methods and Data Collection

The mapping review was conducted following review standards and procedures outlined in [5]. We defined the research question, finalized the mapping review scope, identified inclusion and exclusion criteria, conducted the search, screened papers, and finalized our data. The mapping review was selected to address the differences in the depth and breadth of data from the grey literature. We compiled our data set through two data sources. Our first data set was compiled from published doctoral dissertations from doctoral programs in the US. Our second data set was collected from the National Science Foundation's "Advanced Search" and included accepted NSF Proposals. Both data sets were narrowed to include only items closely linked to "Engineering Education" over a 10-year period (Jan 2011 – Jul 2021).

A. *Dissertations Data Collection and Selection*

Data were collected from the ProQuest Dissertations and Theses data. An initial search of Engineering Education program graduates and dissertation titles was conducted using the department website. Program websites that list published dissertation titles are typically linked to the ProQuest or university database containing theses and dissertation. We selected universities with programs that offer a Ph.D. or Doctorate degree in Engineering Education during the ten-year data collection range. Purdue University, Virginia Tech University, Clemson University, Utah State University met the criteria and are described in [6]. The date range for the dissertation data included dissertations published in Jan 2011 – Jul 2021. A total of 194 dissertation titles were listed across the four universities and 184 linked to a published text that referenced a framework. We searched the full text for the theoretical underpinning identified in the dissertation; the theoretical underpinning(s) could be stated throughout the text and were typically described in the introductory sections or literature review. We focused on theoretical underpinnings that were used to structure the dissertation study.

The specific exclusion criteria for the Doctoral Dissertations were:

- Excluded doctoral dissertations with no reference to a framework
- Excluded doctoral dissertations with unavailable text

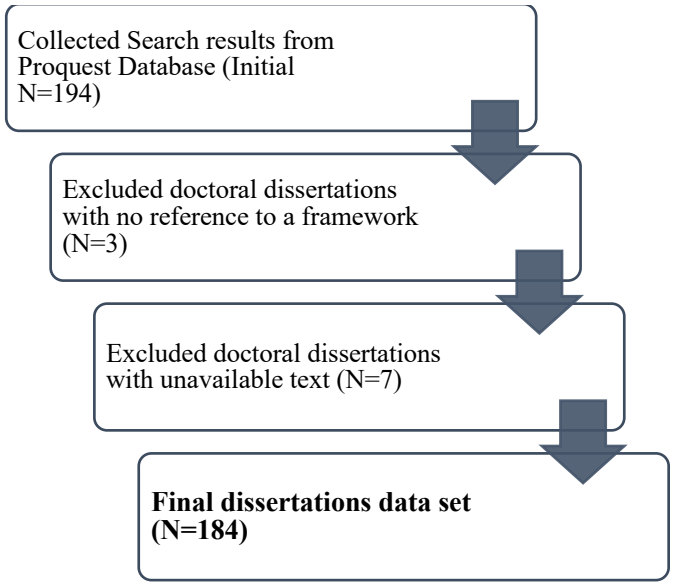

Figure 1: Doctoral dissertations data filtering and exclusion criteria

B. *NSF Proposal Abstracts Data Collection and Selection*

Data were collected from the National Science Foundation Award Advanced Search. The date range for the proposal data included proposal abstracts published in Jan 2011 – Jul 2021. We conducted two searches to collect as much relevant data. The first was using the keywords "engineering education", with no specified NSF Organization for the date range 01/01/2011 – 07/31/2021. The second search used the "EEC – Division of Engineering Education & Centers" as the NSF Organization for the date range 01/01/2011 – 07/31/2021. Our target research scope and population for the NSF Proposals was "higher education." Therefore, any proposals that focused on students and education populations beyond higher education were excluded.

The specific exclusion criteria for the NSF Proposals were:

- Excluded proposals with no reference to a framework
- Excluded proposals beyond the target research scope and population
- Excluded proposals that focus on non-social science framework

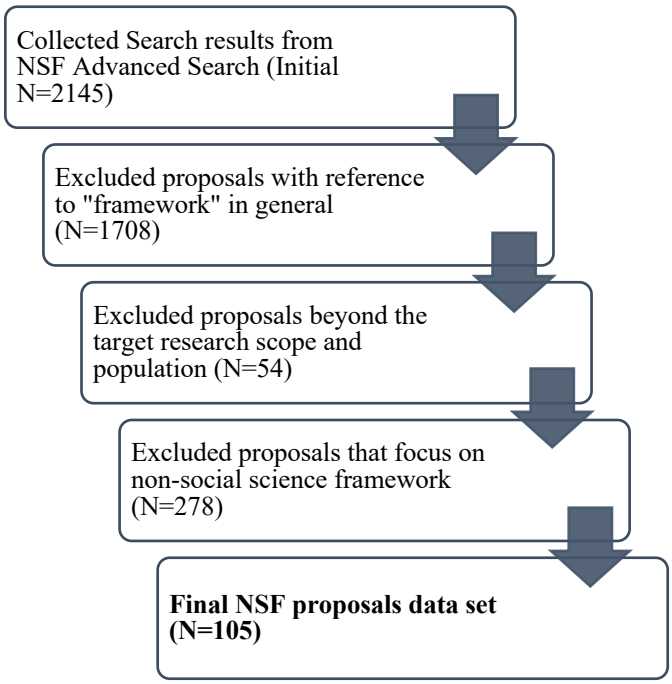

Figure 2: NSF proposals data filtering and exclusion criteria

IV. Analysis and Findings

The first step in analyzing the texts found in the data collection stage was classifying the underpinnings into explorable categories. This was a difficult task because classification in context can be a subjective task. Engineering education as an interdisciplinary field often includes the application of theories and frameworks that have been borrowed from other disciplines. For example, situated learning, which finds its roots in education research, was a theory that was common in both the data sets from our early exploration. In addressing the breadth of the data, we reviewed some EER specific resources to guide our classification. The EER Taxonomy (Version 1.2 Aug 7, 2020) was used as an inspiration to initially classify the variety of theories used in both the NSF

Proposals, and the dissertations [2]. Specifically, "Section 13 – Theoretical Frameworks" influenced how we conducted this process and informed what domains the theories may be coming from. This prompted the exploration of other researcher's categorization attempts. [7], [3] and [8] each provided additional categories that EER has already been classified in the past. A set of general categories was developed and used in Table IV in the Analysis section.

We refer to models, frameworks, and theories collectively as underpinnings [3], and specific definitions are provided in Table 1. We used the four forms of underpinnings, "Model," "Conceptual Framework," "Theoretical Framework," and "Theory" [3, p. 97] to code the text from the proposal and dissertation data. To answer our research question, we focused on what underpinnings authors *commonly* and *explicitly* cite. We tried to remove our interpretation of the author's use of an underpinning and extracted the author's wording from the text to focus on how the authors explicitly included any of the four forms. In the case of both the dissertations and proposals, one or more underpinnings could be associated with each text. Every proposal and dissertation author did not use the same definition we are using from Passey's work, but many authors used the terminology associated with an underpinning, e.g., theory, framework, model. We identified (counted) each use of an underpinning. A proposal or dissertation could explicitly include a theoretical framework and an analytical framework, and we counted each theoretical framework (=1) and analytical framework (=1) that were included in the same proposal. We also noted if an underpinning did not appear in any proposal or dissertation. Tables 2 and 3 are counts of the underpinnings identified in each of our data sets.

TABLE II. CATEGORY REPRESENTATION (DISSERTATIONS) OVER THE 10 YEARS (JAN 2011- JUL 2021). EACH DISSERTATION MAY HAVE MORE THAN ONE ASSOCIATED UNDERPINNING.

	Underpinning	Number of Dissertations
Framework	Analytical Framework	17
	Conceptual Framework	42
	Theoretical Framework	121
	Unidentified Framework	4
	Total	**184**

The nature of Ph.D. dissertations necessitates reviewing and using theory on the dissertation topic. The Ph.D. candidate must include a thorough review of the existing literature in order to position their work and communicate their unique contribution to the field. All dissertations include references for existing work that presents new theory or builds on existing theory. The dissertation text includes terminology related to theory, constructs, and models but may not explicitly relate to its application in their research. To answer our research question specifying what authors *explicitly use in their research*, we coded the dissertations for the use of the underpinning, "Framework," applied to their original Ph.D. research. We also identified the dissertations with no explicitly named framework used.

TABLE III. CATEGORY REPRESENTATION (PROPOSALS) OVER 10 YEARS (JAN 2011- JUL 2021). EACH PROPOSAL MAY HAVE MORE THAN ONE ASSOCIATED UNDERPINNING.

	Underpinning	Number of Proposals
Theory	Theory/Theories	70
Construct	Theoretical Construct	0
Framework	Analytical Framework	0
	Conceptual Framework	2
	Theoretical Framework	29
	Non-identified Framework	27
Model	Analytical Model	0
	Conceptual Model	0
	Theoretical Model	0
	Non-identified Model	5
	Total	**133**

Theory, as defined by Passey [3, p. 97], "considers a broader and deeper concern or context, suggesting the detail of what might be more general, beyond one or a number of contexts" and provides examples, including Unified Theory of Acceptance and Use of Technology (UTAUT) [9] Social Constructivism [10] Constructionism [11] Behaviorism [12]. Engineering Education is an integration of ideas and theory from the engineering and education disciplines as well as other social sciences. We found that proposal and dissertation work utilized theory to inform, shape, guide, and interpret findings. Proposal and dissertation authors identified specific theories or broadly described the use of theory and its relationship to their research.

Over the last decade, many theories have been applied to EER; we identified 20 specific theories, models, and frameworks that were used the most. Table IV lists the 20 theories most commonly used and provides specifics on how often they were included in the NSF proposal abstracts and dissertation text. Social Cognitive Theory, Social Cognitive Career Theory, Communities of Practice, and Intersectionality Theory were the most common in the proposal abstracts. Of the final 105 proposals analyzed, only 15 cited an author for the specified framework. This may be partly due to differences in how authors go about the grant writing process. Some authors may have specific underpinnings selected and built into the proposal from an early stage of the writing process, while others may be including a more generalized underpinning to provide some flexibility to the application. Identity Theory and

Motivation Theory were most commonly used in the dissertation proposals. There were variations on how the theories, frameworks, and models were included in the dissertation texts. Some underpinnings were not commonly used, e.g., a theoretical framework only appeared in one dissertation in the data set. Some authors used underpinnings to discuss a more broad and general application of a framework or model, e.g., motivation or self-efficacy. Some dissertations use multiple underpinnings to create their own module used to guide their research, e.g., a "conceptual model."

TABLE IV. COMMON THEORY, FRAMEWORKS, AND MODELS (JAN 2011-JUL 2021)

Name of Underpinning	NSF Proposal Count	Dissertation Count
Social Cognitive Theory	6	3
Social Cognitive Career Theory	5	7
Communities Of Practice	5	2
Intersectionality Theory	5	5
Situated Learning	4	6
Social Identity Theory	3	1
Identity Theory	0	8
Social Capital Theory	3	1
Community Cultural Wealth	3	1
Socio-Constructivist Learning Theory	3	0
Constructivist Theory	0	4
Collective Impact Framework	2	0
Diffusion Of Innovation	2	1
Cognitive Load Theory	2	1
Change Theory	2	3
Expectancy-Value Theory	2	4
Socialization Theory	2	1
Motivation Theory	2	0
Self-Efficacy	2	4
Kotter's 8 step Model of Change	2	0

This work has some limitations in the regional context and the data sets involved. Firstly, the scope of the review of grey-literature was limited to the artifacts in the United States. We used publicly available data for both data sets. For the dissertations, as mentioned in the exclusion criteria, there were some dissertations that were under embargo, and the full text was not available at the time of data collection. These dissertations were removed to ensure all the artifacts included in the data set could be compared together. For NSF awarded proposals, using only publicly available data from the NSF Award Search database only includes proposals that were awarded. It is very likely that authors in the field of EER are using other underpinnings in their work. However, this may not be represented in the data sets. Another limitation may be due to the nature of proposal writing, where the artifact is written specifically to answer the directionality of the proposal call, and so the instructions may influence the way that the proposal is written. If the authors are required to tie a theory or framework to the work they are doing, this may influence the likelihood that authors will describe these items in the proposal abstract. The level of detail presented in the proposal may be shallower than that which would be presented in a full paper or dissertation. It is also common for proposals to mention a broad framework without specificity toward the specific flavor of the framework that is intended.

V. DISCUSSION

Engineering Education is a diverse and interdisciplinary field so it was not surprising that most of the underpinnings originated or were developed from other fields. In this paper we analyzed US proposals and dissertations and the theories they commonly and explicitly used. To build on the work reported in this paper, we recommend reflecting on how these theories are used and applied in other fields. We deliberately picked proposal abstracts and dissertation because they provide a different perspective or ideas by the nature of the document. We realize that the purpose of a proposal for research and the purpose of a dissertation documenting completed research are different in the amount of text they produce, how that can shape what information is reported, and how the respective authors focus their ideas. Our recommendation for new authors in the field is to explore these publication types in addition to journal articles, conference proceedings, and other more commonly cited publications.

The mapping review highlighted the variety and depth of underpinnings used within engineering education research. The use of underpinnings and findings from the study expands the singular notion of "theories" that has often found favor within EER [13]. Some authors are very specific in their selection of a specific underpinning, regarding who and what domain the underpinning is associated with (i.e., *Bandura's Social Learning Theory* from Psychology). But others describe the underpinning vaguely in both ways. This is challenging from the scope of the mapping review, as the details across all the artifacts may differ. This may also be because of the differences between the details with which a dissertation is written, versus that with which a proposal abstract may be written. Further research exploring the field's specificity of underpinnings may highlight informative results.

The mapping review also highlighted differences in definitions across both specific and general underpinnings. For the review, we strictly followed how the authors described the underpinning. For example, if an author stated that *Social Cognitive Theory* was being used as a framework, it was counted as a framework. However, there may be language considerations at play here that make defining the underpinning unclear and confusing. It is important for authors to pick the correct underpinning underlying the work as it highlights how it will be used, but also the contributions that will be made based on the underpinning.

Even when an underpinning is specifically mentioned, there may be variations of the underpinning that make it difficult to pinpoint exactly which specific version of the underpinning the authors are referring to. For example, some authors stated that

they were broadly using "Identity Theories." This implies that the authors recognize the breadth of variations that have spawned within the term of Identity Theory, and that they were planning on using more than one theory in the scope of the work. However, without the details of which specific variations the authors are using, the nuances of the theory perhaps become less identifiable. When possible, specific theories should be outlined with identifiers wherever relevant to the authors who have provided the grounding for the relevant theories. This contextual information is very helpful for new members of the EER community.

Through exploring how authors specifically describe underpinnings in their work, it seems as though EER scholars interchangeably use the four forms of underpinnings. Theories are sometimes presented as frameworks, or models. While this is dependent on the way the authors are using the underpinning in their work, it is important that these forms are understood as distinct terms. The underpinnings used in engineering education research are intended to shape, guide, and help interpret research and scholarly work. Our intent in conducting the work presented in this paper was to identify the common and explicit underpinnings used in grey literature. We also hope that this work also encourages readers, possibly engineering education researchers at any stage in their career, to reflect on how they have used underpinnings in their own research. The interpretive utility of theory may have led you to think about your approach and/ or findings from a new perspective. The abstraction of an underpinning can have more concrete impacts if you use the knowledge of theory, models, and frameworks in your own educational settings.

Overall, the findings from this study contribute to the literature within EER that has previously utilized bibliometric and related approaches [14]-[16]. That work has highlighted the development of different epistemic and relational networks that have developed in the field over time. The current study adds nuance to those findings through a more qualitative and in-depth study to better understand the use of frameworks. This work also extends prior work by using grey literature whereas most related prior work uses journal papers or conference proceedings to understand the field. This comparison of this study with prior work brings out the need to develop complementary techniques that combine bibliometric analysis and data mining with more contextual analysis.

VI. Conclusion and Future Work

Grey literature, specifically research proposals and dissertations, provides a unique insight into how and what underpinnings are being used to shape the field of engineering education. In this paper we present a study that examined the use of these underpinnings in dissertations and research proposals over the past decade. As we look to the next decade of EER, we hope to analyze the longer-term effects of underpinnings in research. We would like to see if and how the theory identified in the nascent research proposals is propagated in the completed research documenting a unique contribution to the field of engineering education. We were not able to make direct connections or causality across proposals and dissertations over the last decade, but we did see a trend of the explicit use of underpinnings.

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