

## **The "Fibonacci Sequence" of Critical Theoretical Frameworks: Breaking the Code of Engineering Education Research with Underrepresented Populations**

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# The “Fibonacci Sequence” of Critical Theoretical Frameworks: Breaking the Code of Engineering Education Research with Underrepresented Populations

## Abstract

Understanding how to accurately use critical theoretical frameworks can assist in analyzing the climate of engineering, its impact on underrepresented student populations, guide future research, and provide an opportunity to further improve the ways in which engineering can become more inclusive and not simply superficially diverse. In this work in progress literature review, we describe how critical frameworks are utilized and emphasized in engineering education research. The purpose of this literature review was to determine whether the critical frameworks achieved the goals of *praxis* and *concientización*. To achieve this goal, we focused on the contextualized understanding of the critical theoretical frameworks to facilitate *conciencia*.

## Introduction

The plethora of research on underrepresented minorities in engineering education has resulted in a substantial number of articles on the topic. Some of the research studies have tried to understand the state of underrepresentation in engineering<sup>1-4</sup>, their academic trajectories<sup>5-7</sup>, factors that impact their retention and participation<sup>8-12</sup>, and their histories and experiences<sup>13-15</sup>, among others. These studies have discussed the potential of different initiatives to provide support to underrepresented students. Due to the recent call for broadening and participation of underrepresented students from the National Science Foundation<sup>16</sup>, there has been several attempts to utilize asset-based frameworks that may represent the perspectives of underrepresented populations in engineering.

Recent engineering education research has focused on uncovering those complex realities through critical theoretical frameworks. References and relevant work done in other research areas (e.g., education, social sciences, law), rooted in specific critical theories, aim to provide an understanding of the underrepresentation phenomena in engineering. These frameworks also provide contextualization and background for the studies at hand.

Critical theoretical frameworks were developed to unlock “hard and complex truths” with the intent to critically analyze race, privilege, and marginalization of people of color from a legal standpoint. Eventually, critical theoretical frameworks were adapted to educational research to analyze complex systemic inequalities in education. For instance, one of the initial purposes of using critical frameworks in education was to challenge deficit thinking models. Although the deficit models lacked empirical validations, critical theoretical frameworks had a powerful influence in educational practice. These frameworks challenged the idea that students’ skill levels and attitudes were to blame for their failure rather than the lack of structural changes in the schools. Thus, critical theoretical frameworks have played a very important role in uncovering these inequalities by emphasizing the “histories, experiences, cultures, and languages that have been devalued, misinterpreted, or omitted within formal educational settings” (p. 106)<sup>17</sup>.

When considering using critical theoretical frameworks in any context of education, special attention must be paid to identify the unique and properly situated algorithm (similar to a Fibonacci sequence) to prevent misappropriations and formulaic assumptions of the phenomenon being studied. In the context of engineering, understanding how to accurately use critical theoretical frameworks can help engineering education researchers to properly analyze the climate of engineering, its impact on underrepresented student populations, and guide engineering education research whose findings can identify interventions that are “inclusive and not simply superficially diverse” (p. 54).<sup>18</sup>

As mentioned previously, the aim of critical theories is to challenge the power structures and dynamics that oppress individuals. Critical theories challenge the value of power structures by valuing the individual over the organization. Therefore, critical theories allow us to emphasize the holistic student (i.e., their histories, social and economic backgrounds, languages, experiences) as opposed to valuing the hierarchical structure and labels (e.g., agglomerated demographic information) traditionally presented by education systems and bodies of research. According to Paulo Freire<sup>19</sup>, care must be taken to ensure that as educators/researchers, we do not become the “oppressor”:

The oppressor is solidary with the oppressed only when he stops regarding the oppressed as an abstract category and sees them as persons who have been unjustly dealt with, deprived of their voice, cheated in the sale of their labor – when he stops making pious, sentimental, and individualistic gestures and risks an act of love. True solidarity is found only in the plenitude of this act of love, in its existentialism, in its praxis. (p. 50)

As described by Freire, the “appropriate use” of critical theories in engineering education research requires the educator/researcher to fight alongside the underrepresented groups and supporting their own quest<sup>19</sup>. To fight alongside means the educator/researcher does not make “pious, sentimental, and individualistic gestures” (p. 50)<sup>19</sup> but assumes a role to facilitate *conciencia*, or “the process by which humans become more aware of the sources of their oppression” (p. 7)<sup>20</sup>.

The authors of this Work in Progress paper aimed to analyze how critical frameworks are being used in engineering education and identify if there are elements not being addressed in these areas of research. Thus, the purpose of this literature review was to explore, synthesize, and critically analyze example research studies that use critical frameworks in engineering education. By identifying areas of gap in the use of these critical frameworks, we can begin to uncover ways that educators/researchers can facilitate, disseminate, and advocate for a holistic consciousness of the factors that many underrepresented students face in engineering.

## **Critical Theories**

According to Horkheimer<sup>21</sup>, there is a distinction between traditional and critical theory. Traditional theory seeks to only understand or describe society, while critical theory seeks to critique and change society as a whole. Critical theory recognizes the complexity of social processes and its main task is “to reflect upon the structures from which social realities and the

theories that seek to explain it are constructed” (p. 139).<sup>22</sup> Although critical theory originated in the Frankfurt School with a focus on a criticism of modern social structures,<sup>22</sup> critical theory prevails in other fields such as sociology and education,<sup>23-25</sup> pedagogy,<sup>19, 26-29</sup> and other areas including feminism and social sciences.<sup>30-32</sup>

Critical theories not only look at the complex social processes, but also explore the circumstances that enslave individuals. Horkheimer<sup>33</sup> indicated that critical theory seeks “to liberate human beings from the circumstances that enslave them” (p. 244). Thus, these frameworks have been used in different areas to describe the ways in which systemic oppression has created misfortune for underrepresented populations. For instance, critical race theory emerged from legal scholarship to provide an overview of the permeation of racism through the legal system.<sup>34</sup> Eventually, scholarship in education integrated critical race theory to examine and challenge the traditional paradigms that exist in the educational system. Moreover, the goal of critical race theory has been used as a framework to focus on the experiences of students of color, challenge the traditional paradigms, texts, and to provide agency and empowerment to the oppressed.<sup>35</sup>

Another example is the way that other sociocultural frameworks, which are grounded on critical thought, have challenged deficit models in education. Deficit thinking refers to the notion that students (particularly low-income, minority students) fail in school because such students and their families experience deficiencies that obstruct the learning process (e.g. limited intelligence, lack of motivation, and inadequate home socialization).<sup>36</sup> Lee<sup>37</sup> argued that by learning from the students’ knowledge resources, ways of knowing, doing, and being, teachers could facilitate and promote learning in ways that are relevant for students. Providing the space where education can become relevant is, in some ways, what Paulo Freire described as the action of fighting alongside the individual rather than providing simplistic solutions to the situation.<sup>19</sup>

There is also the combination of different critical theories to describe complex social dynamics. For example, Marx and Larson<sup>38</sup> described how two different theoretical frameworks were used to analyze the experience of Hispanic students in a predominantly white school. Critical race theory was used to “understand a system of advantage based on race rather than a series of isolated acts based on individual feelings of hatred” (p. 259). A Critical Whiteness lens was also used as a theoretical framework to describe the exclusion of children of color. Critical Whiteness explores how society has been, and continues to be, constructed under White cultural norms and how it creates privilege for the dominant White race. The use of both frameworks created a perfect amalgamation that explained how some sectors of the population are so marginalized, even when colorblindness is present, that racism is “apparently” neglected.<sup>38</sup>

Explaining inequity through these critical frameworks was very effective because it showed the views of students of color and White teachers. Describing both points of view, as well as the justifications to abstain from implementing specific recommendations, made it clear that Whites still enjoy a certain privilege in society and that their norms is what creates an environment of oppression.<sup>38</sup> Moreover, the study also pointed out the different stigmas that many Hispanic students carry because of the misconceptions and preconceptions created by the White majority. The teachers’ colorblind approach to teaching – the act of teachers saying they don’t see race but only people – was described as the perpetual discriminatory tactic used in the education system.

Claiming that one is colorblind is in itself a form of racism, and the teachers' colorblindness did not let them see their own racist comments, misconceptions, and tendency to give privilege to White students.<sup>38</sup>

Critical thought has also played an important role in challenging the status quo in different contexts. Guajardo and Guajardo<sup>39</sup> used critical theory lenses to describe the importance of community organization to dismantle the educational structure created by the "separate but equal" rhetoric in South Texas. They focused on the narratives, or storytelling, of the participants in the study to create counter-stories, which validated their histories, experiences, and ways of knowing. "Storytelling and counter-storytelling these experiences can help strengthen traditions of social, political, and cultural survival and resistance."<sup>35</sup> These counter-stories, which recount the stories of struggle within a larger sociopolitical context, validate the experiences of racism or sexism of the oppressed.<sup>35</sup> Storytelling and counter-narratives have become a very important component of LatCrit – a variant of critical race theory used in Latin@ and Chican@ studies.<sup>35</sup> Stories or narratives construct the reality of those who are marginalized, and they count as knowledge that provides a form of shared reality, creates bonds, and represents cohesion, understanding and meaning.<sup>39</sup>

The study explored the key characteristics of critical race theory (embedded normal nature of racism, permanence of racism, critique of liberalism, interest convergence, property rights in whiteness and storytelling) and used them to reach the audience in a compelling way.<sup>39</sup> The type of methods used by Guajardo and Guajardo<sup>39</sup> reflect the objective of critical theories: to give voice to those who are marginalized. The study was grounded on the voices of those who participated in the events of 1968 and contributed to the sociopolitical and educational changes in the South Texas region. The type of information collected included oral stories, narratives, interviews, videos, and written and pictorial representations. They embraced the concept of "hybridity" in critical theoretical frameworks, which is the integration of different types of data collected that can be used as knowledge and storytelling, as mentioned by Richard Delgado.<sup>34</sup> Moreover, the authors relied on the oral narratives of the participants as a way to create awareness and "destroy the mindset" of those involved in this adverse situation.

Thus, the uses of critical theories have provided a new perspective to research in education and the social sciences. Critical theories advocate for an approach that is not primarily positivist or the use of methods that classify the social world in an objective way with casual connection. These frameworks illustrate the ways in which context, gender, culture, society, and other factors can be analyzed through a critical lens in order to achieve equity. The purpose of integrating critical theories to the engineering education research is to critique and change society as a whole,<sup>21</sup> and reflect on the world and its dynamics through reflection.<sup>19</sup> Unfortunately, using these critical lenses to understand the experiences of underrepresented minorities in engineering can be detrimental if *praxis* (the fusion of theory and action) and *concientización* (choose a course of action based on reflection)<sup>19</sup> are not achieved.

## **Research Questions**

The purpose of this literature review is to shed light on the use of critical theories in engineering education. The objective is to describe how critical frameworks are being employed and

emphasized in engineering education research. We believe a systemic review is necessary in order to remove ourselves from reductionist paradigms and achieve *praxis* and *concientización*. This literature review was guided by three questions:

1. What are the common types of critical theoretical frameworks used to study underrepresented populations in engineering education?
2. Which populations are being studied in engineering education using critical theoretical frameworks, and which populations are not being considered?
3. How are these critical theoretical frameworks used in the research methodologies?

## **Methods**

The databases ERIC, IEEE Xplore, Journal of Engineering Education, ASEE PEER, Journal of Women and Minorities in Science and Engineering, and the Journal of STEM Education were used to locate primary sources. The descriptors “critical theory,” “underrepresented minority,” “critical race theory,” “feminism,” “conciencia,” and “intersectionality” were used to locate primary sources. These descriptors were also used in conjunction with other descriptors such as “underrepresented populations,” “Latino,” “Hispanic,” “African American,” “Native American,” and “women.” Several articles were identified as potential sources of information, but only articles that met the following inclusion criteria were reviewed: published after the year 2005, used theoretical critical frameworks, and investigated K-16 academic engineering education. The papers were divided into the types of critical frameworks employed in the research. In total, there were 22 articles reviewed that represented a wide variety of critical thought frameworks. Each article was reviewed by at least one of the three authors in detail using an agreed-upon coding sheet.

A coding sheet was developed based on the characteristics significant to each study evaluated. These categories on the coding sheet included identifying the purpose of the study, the methods used, the type of data collected, the population involved in the study, and relevant findings. Additionally, we used our guiding questions to understand the ways in which the critical theoretical frameworks were used in these publications. After reviewing the articles, we reviewed the preliminary findings and patterns they saw in their respective notes. The lead author reviewed the notes and preliminary findings to guide the final review.

## **Limitations**

The articles described in this literature review do not cover all the critical theoretical frameworks existing in the literature. Although there is an emergence of critical theoretical frameworks in engineering education, there are several fields, such as education and sociology, which have prominently used these frameworks, that were not considered in this literature review. We opted to exclude studies in those fields to have a better representation of the use of these critical theoretical frameworks by engineering education researchers.

In addition, this is a work-in-progress and does not address the use of critical theoretical frameworks that are not clearly defined by the authors. For instance, there are variants of feminist thought, such as *Mujerismo* or Womanism, that were not included in the literature review because of the descriptors used. While there has been at least one other attempt at

studying the types of frameworks used in studies about students of color in STEM,<sup>40</sup> to the authors knowledge, there has not been a previous attempt at reviewing studies that use critical theoretical frameworks. Nonetheless, this Work-in-Progress literature review may begin to shed lights on the current state of engineering education research with regards to the selection, use, and representation of findings using critical theoretical frameworks as their lens.

## Results and Discussion

The articles identified in this work-in-progress literature review illustrate the growing number of studies that employed a critical theoretical framework to better understand the histories and experiences of underrepresented populations in engineering. Most of the studies incorporated feminist theory or critical race theory to analyze the social dynamics in engineering. Other common types of critical theoretical frameworks included intersectionality, storytelling and counter-narrative, funds of knowledge, Bourdieuan analysis, community cultural wealth, and other variants of feminist thought such as Womanism. The variety of critical theoretical frameworks indicated the openness and effort from the engineering education research community to integrate theoretical lenses to challenge the status quo. However, there were areas that also demonstrated a need to more deeply engage in the full spectrum of critical theoretical frameworks in engineering education.

The studies included in this literature review demonstrated a need for more holistic and disaggregated analysis and dissemination of the experiences of underrepresented populations in engineering. In the majority of articles reviewed, critical theoretical frameworks were used to guide the research, yet, after careful analysis, it was noted that the frameworks were not explained in a way that could lead to either *praxis* or *concientización*. For example, while one of the studies was aimed to study feminist theories, it was surprising that the authors opted not to expand their literature base to international and national non-English language publications, particularly when exploring the Intersection and Interactional Feminist Theories in engineering.

Also, it was observed that most of the papers included in this literature review considered a wide range of underrepresented student populations, rather than focusing on the unique experiences of one population. Most of the studies focused on the experiences of women in engineering but racial/ethnic group findings were clustered. For example, one paper discussed the experiences of Native Americans but findings were clustered with other ethnicities or races (i.e., Hispanics and African Americans). Our findings positioned us to question if selection of critical frameworks for engineering is effectively describing the lived experiences of underrepresented individuals when participants get clustered with other groups. While there is importance in presenting a lens that reaches a wider population (breadth), critical frameworks also require *depth* in the way that the histories, experiences, cultures, and languages are researched and presented in the literature. As more and more studies in engineering education begin to focus on other dimensions of underrepresentation such as language, immigration, ethnicity, culture, identity, phenotype, sexuality, among others, it will be important for educators/researchers to have a targeted lens when exploring these complex yet important phenomena.

Another example was found in studies of “focused” underrepresented populations in engineering. In several studies, the term Hispanics were mentioned as the population of study yet there was no

distinction between this definition and Latin@/Chican@ nor were there references about the community, demographics, language, etcetera, that would precisely "de-cluster" these groups. The same applied for engineering education research on Native American and African American populations whose demographics, origins, and sub-cultures were not considered. As future uses of critical frameworks in engineering will continue, it will be important to consider more purposeful sampling for these underrepresented groups. Limiting sampling methods and approaches in critical analysis work could be detrimental to the goal of *praxis* and risk the unintended invalidation or belittling of cultures, languages, and experiences that are traditionally marginalized.<sup>17</sup>

In addition, the authors noted the use of language selected to describe the experiences of these underrepresented groups in engineering. For instance, many of these studies focused on describing a "deficiency" first (i.e., the lack of language proficiency or support networks) rather than a characteristic that these populations could "voice" to challenge deficit models, or describe the normative bases for social/educational inequity.

Finally, although several studies explained to detail the purpose and background for the studies, there was limited context to the studies. It was difficult to understand the overall time-period in which these studies were completed. No holistic view of the events that lead to that specific situation, or the events happening at a specific time, make it difficult to engage others in either *praxis* or *concientización*. Freirean pedagogy argues that it is important to connect back to history of a population in order to provide a context that can validate the experiences of the oppressed, and to eliminate the idea that the oppressed are incapable of determining their own liberation.<sup>19</sup>

## **Conclusion**

Underrepresentation in engineering is a very complex and multi-faceted research process. While critical theoretical frameworks are beginning to be used to challenge the status quo, a closer examination of the factors important in the use of these frameworks is needed to ensure a deeper exploration of the phenomena at hand. It is only by careful selection, use, and application of these critical frameworks that engineering educators/researchers can apply the "Fibonacci sequence" or meticulous approaches to "break the code" of underrepresentation in engineering.

One beginning step towards breaking this code, is to acquire a better understanding of the histories and experiences of underrepresented minorities in engineering. This may imply that as we focus on a disaggregated underrepresented population we must also consider the additional intersectional and interwoven layers that that a particular population carries (e.g., culture, gender, sexual orientation, (dis)abilities, race, ethnicity, and ways of knowing).

Another element to consider is that critical researchers do not only describe an event or experiences; they ask questions of power, privilege and oppression. As such, as engineering educators/researchers, there must be a close introspection to own biases and limitations, so that we can begin to step away from "clustering" views of underrepresentation in engineering to move toward action, reflection, *praxis*, and *concientización*.

Future work will expand our literature review to explore elements of “insider” and “outsider” perspectives in doing critical theoretical frameworks, the value of storytelling, and use of racial-specific critical theoretical frameworks in engineering. Storytelling is a fundamental component of Critical Race Theory because it challenges the current norms and reductionist constructions of underrepresented ethnic minorities.<sup>35</sup> Storytelling is an important part of culture and a community, and as part of a community the engineering education research community has done a good job in starting this story. There has been an emphasis on trying to understand the experiences of underrepresented minorities in engineering. Nonetheless, a story is not complete until it integrates not only some of the characters, but also their environment, history, beliefs, values, ways of knowing, doing and being. Similarly, as part of the engineering education community, we must add more factors to this story – the stories of struggle, subjugation, and oppression.

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