The Quest for URM Doctoral Persistence: An Analysis of Feedback Loops in the Academic System

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Abstract. Studies have shown that the graduation rate for underrepresented minorities (URM) students enrolled in engineering doctorates is significantly lower than their peers. In response, we created the "Rising Doctoral Institute (RDI)". This project aims to address issues that URM students encounter when transitioning into a Ph.D. in engineering and their decision to persist in the program. To suggest institutional policies that increase the likelihood of URM students to persist in their doctorate, we identify and analyze some factors in the academic system that reinforce or hinder the retention of URM students in doctoral education.

Although the factors that influence persistence in URM students have been largely studied as direct causes of attrition or retention, there is a need for a system perspective that takes into account the complexity and dynamic interaction that exists between those factors. The academic system is a complex system that, by nature, is policy resistant. This means that a positive variation of a factor can incur unintended consequences that could lead to a negative variation in other factors and ultimately hinder the positive outcomes of that policy.

In this work-in-progress article, we analyze the dynamics of the factors in the academic system that reinforce or hinder the retention of URM graduate students in engineering. The purpose is to build some of the causal loops that involve those factors, to improve the understanding of how the complex system works, and prevent unintended consequences of institutional policies. We used Causal Loop Diagrams (CLD) to model the feedback loops of the system based on initial hypotheses of causal relationships between the factors.

We followed a process that started with establishing hypotheses from a previous literature review, then using a different set of articles we identified the factors related to the hypotheses and the causal links between them. Next, we did axial coding to group the concepts into smaller categories and established the causal relations between categories. With these categories and relations, we created the CLDs for each hypothesis. For the CLDs that have connections missing to close the loop, we went to find additional literature to close them. Finally, we analyzed the implications of each CLD.

In this article, we analyze and describe three major CLDs found in literature. The first one was built around the factor of having a positive relationship with the supervisor. The second centered on the student's experience. The third focused on factors that relate to university initiatives.

I. Introduction

In the 2018 report, *Graduate STEM education for the 21st century*, the National Academies of Science, Engineering, and Medicine stresses the need to have representation of all segments of society in graduate schools and change the trend of exclusion in STEM fields [1]. In engineering some underrepresented minorities (URM), have significantly low representation in Ph.D. programs. This is the case for African Americans, who received only the 3.5% of doctorates in Engineering in 2015; Native American, 0.25%; Pacific Islands 0.021%, and Hispanic American, 6.19%. [1]

To help URM students to overcome the challenges they face as minorities in their doctorate, we created the Rising Doctoral Institute (RDI), a project funded by the National Science Foundation (NSF). The RDI consists of an intervention of one week, in which URM students receive guidance and information that helps them navigate the transition to the Ph.D. and provides them with a support network [2]. The goals of the RDI program are (1) to examine the effect of early interventions for doctoral students on the transition into the engineering doctorate, and (2) to develop sustainable models for institutions to implement on their campus to help URM students transition into the doctorate [2].

As part of these goals, the RDI project proposed to research the academic system's influence on the persistence and retention of URM students, and how the RDI intervention could impact the factors in the system to generate a change that favors URM students' persistence [2].

The academic system is composed of actors, elements, and concepts that have complex and dynamic interactions with each other [3]. We are interested in understanding and handling the complexity of the academic system that impacts the persistence of URM students. In this paper, we consider that the academic system, as a social system, is policy resistant, which means that well-intended interventions can cause unanticipated consequences that diminish the positive outcomes of the intervention. To avoid policy resistance, a social system must be analyzed as a whole system in which elements interact with one another over time [4][5].

As proposed in [4], to address the complex nature of the academic system we used a System Thinking approach, a holistic perspective of the connections between all the elements of a system. With this approach, we aim to understand the connections and interactions between the factors that led a URM student to persist or withdraw from a doctorate program. The System Thinking perspective has used System Dynamics Model (SDM) as a tool to model the complexity of the social world [4]. SDM comes from the control theory in engineering as a method to develop mathematical models of nonlinear systems. We will use the principles of this method to model the relations between the factors of interest for our study.

Previously to the work presented in this paper, it was done a literature review to identify the factors in the academic system that have been reported as having an impact on URM students' persistence and retention [6]. In this Work in Progress paper, we present the first steps of the SDM method, which is to build the Causal Dynamic Loops (CDLs) that relate to students' persistence, using the results found in [6].

II. Theoretical Background

A. RDI initiative and interventions

The Rising Doctoral Institute is a multi-day intervention for URM engineering students who are starting their doctoral program. It was created to help students to learn about how to face challenges and to define management strategies that increase their odds to persist in their doctoral program and succeed in getting their degree.

A first pilot intervention was held in the summer of 2019, in which 17 students from different universities across the US participated [2]. It consisted of workshops and discussion sessions with topics that research has shown impact students retention (e.g. unwritten rules, time management, relationship with the supervisor). The results of this intervention showed that it helped participants to meet other students that looked like them, increasing their sense of belonging, and gaining an understanding of the doctorate [2].

In the summer of 2021, a second online intervention was done with 34 participants from different universities across the nation. Based on this intervention, the research group enhanced the RDI model and invited administrators of 5 universities to join the project and host a local RDI at their institutions during the summer and fall of 2022. A description of these interventions and their assessment will be presented in a future publication.

B. Modeling Social Dynamic Systems

Modeling social systems is a challenge because of the difficulty of transforming social constructs into mathematical variables that could be then included in equations [7]. Bronson & Jacobsen [7] propose a methodology to model social systems that change over time using a System Dynamic approach. They first select the concepts that are involved in a particular theory, then they establish a general definition that could be applied without ambiguity to each concept. Next, they assign or convert each concept into a variable that has a unit of measure; they highlight that the unit of measure must accurately represent the concept, be reliable, and match measurable entities in the real context of the system. After the variables' definition, they propose to create causal-loops diagrams (CLD), which consist of connecting concepts using one-way arrows that indicate a direct cause-effect correlation. And finally, they use a rate-level diagram, to create the final model of the social system. Along with the description of the methodology, Bronson & Jacobsen explain that the creation of the relationships and functions between variables depend on the quantitative data available from social research. The data provided by social research allows the building of partial theories that are represented in the CLDs and can be tested in the future and refined using the Social Model fed with different data sets. In this study, we followed Bronson & Jacobsen's methodology to create some of the CLDs of the SDM of persistence of URM doctoral students.

C. Previous literature review

Before the work presented in this paper, a selection of concepts was done through a literature review [6]. Seventeen papers which topic was the experiences of students in STEM and engineering programs were analyzed to look for factors that impact persistence. The factors found were grouped into four categories: Advisor-Advisee Relationship, Student Experience, Faculty-Student interaction , and Academic support. The first category included factors that correlated with the quality of the relationship between the student and the student's advisor and the support received from this advisor. Some of these factors are productivity, self-efficacy, and commitment. The second category, Student experience, grouped the factors related to the Expectancy Value Theory [8], such as the perceived cost, the intrinsic and extrinsic motivation, and the sense of belonging. The Faculty-Student interaction refers to factors that come from the faculty professors, besides the advisor. The latter category includes factors such as receiving advice, mentorship, or special attention from a professor. Finally, the academic support category included factors that are related to the institution, for example, participation in research projects previously to the Ph.D. program, academic preparation, clear information about the steps and expectations in a Ph.D., and graduate student groups, among others.

The literature review provided factors and correlations that allow us to define initial hypotheses of causal relationships. These hypotheses are presented in the Results section.

III. Purpose

This work in progress paper presents the construction of three initial Causal Loops Diagrams that connect the factors involved in the persistence of URM students in Ph.D. programs, with the aim to answer the following research question:

> **How does the dynamic between factors in the academic system impacts the persistence and retention of URM students?**

Further research will be conducted to look for more CLDs and their integration to form the SDM of URM doctoral students' persistence. Building the SDM will allow us to understand the factors´ dynamics that help or hinder URM students' completion of a doctorate program as well as identify potential unintended consequences from institutional policies.

IV. Methodology

To build the CLDs, we used the categories found in the previous literature review [6] to draw three hypotheses about loops that reinforce the attrition or the persistence of URM students in doctoral programs. Then, we identified in a different set of articles [9]-[12] causal links between factors related to the built hypotheses. Because each article used different words and phrasing for similar concepts, we did an axial coding to reduce the factors into smaller categories. Next, we defined the causal relations between categories. With the causal relations, we created the CLDs

for each hypothesis. The CLDs had a missing relationship to be closed loops, so we did an additional literature review to find additional causal relations. Finally, we analyzed the implications of the causal loops found.

V. Results

A. Hypotheses

In the previous literature review [6], the factors that affected persistence were grouped into four categories. In this Work in Progress, we started by building hypotheses for the first three categories: Advisor-Advisee Relationship, Student Experience, and Faculty-Student interaction. The fourth category, Academic support, which includes elements related to a higher level of the institution, was left for future study.

The first hypothesis relates to the relationship between the student and the advisor. In the literature review, it was found that factors such as productivity, self-efficacy, and commitment increase when there is high quality in the supervision and the advisor gives the student professional support [6]. The hypothesis that we draw is that there are elements of the relationship between the advisor and the student that impact the student's motivation, which in turn affects the student's productivity or commitment. If those elements change negatively, productivity and commitment can decrease. As a result, the relationship with the advisor can worsen and create a causal loop that could hinder the student's motivation to persist in the program.

The second hypothesis takes into consideration the factors in the student's experience. The literature shows that the sense of belonging is an important factor in URM students because it has an impact on productivity and motivation [6]. The hypothesis drawn in this case is that there are factors in the academic system that increase the sense of belonging in URM students which can create a positive loop that led to persistence.

Finally, we use the factors in the category of faculty-student interaction. The literature shows that mentorship increases success in graduate students, especially if the mentor is from the same ethnicity as the URM student. Interaction with faculty members increases the students' exposure to information, and their confidence in their professional abilities and helps them to create expectations about their career path [6]. Therefore, we worked with the hypothesis that there are factors that can create a positive loop between the faculty-student interaction or mentorship that increases the students' persistence.

B. Axial coding and casual relations

We searched articles [9] to [12] for references to relationships between concepts that were described as part of completing a Ph.D. or the experience of URM students. For example, from Virtanen *et al.* [12] we extracted a relationship between the concepts of "participating in activities of scholarly community" with "student engagement". We extracted a total of 167 concepts and 143 relationships within them. To facilitate the analysis and construction of the CLDs, we did an axial coding to group the concepts into 38 thematic clusters with a key label for

each one. The label was selected to best represent the concepts included in the cluster and to match the names of factors found in the literature. Following Bronson & Jacobsen [7] we established a definition for each cluster.

Table 1 presents the list of the cluster and table 2 shows examples of definitions and concepts included in some clusters.

Table 1. List of clusters that grouped the initial concepts.

Acquisition of knowledge	Autonomy	Change of degree	Diverse learning
Diversity in STEM	Economic constraints	Environment	Engagement
Equity	Eureka moments	Experienced Well-being	Experiential education
Feedback	Future uncertainty	Independence	Institutional initiatives (non-university)
Institutional outcomes	Mentorship	Mindset	Motivation
Number of URM	Persistence	Personal investment	Positive perception of STEM
Positive relationship with supervisors	Relatedness within academic communities	Retention	Self-efficacy
Sense of belonging	Sense of contribution	Socialization	STEM characteristics
Stereotypes	Student recruitment	Success	University actions (policies)
Demographics	Familial factors		

Table 2. Examples of clusters with their definitions and concepts grouped into

Cluster's key concept	**Definition**	**Concepts included**
Positive relationship with supervisors	A meaningful, helpful, and/or personal connection between a doctoral student and a faculty member overseeing the student/project.	Supervisor's contribution to the doctoral project, Supervisor's attitude, Interactions with an advisor, Intellectual support from an advisor
Self-efficacy	The student's belief in their capacity to execute behaviors necessary to produce specific performance attainments.	Feelings of being effective, Efficacy as a researcher, Competence
Socialization	The formation and maintenance of a supportive connection between the doctoral student and others including family, friends, and community.	Social integration of students, Understanding of doctoral programs (community and friends), Social support
University actions	Measures that an institution formally can take to foster a supportive environment suitable for all students to succeed (especially URM).	Early interventions, Frequent interventions, Enhanced academic support, Program evaluations, Diversity and inclusion culture, Professional development interventions, Community building, Participation incentives, Training/educating URM

After defining the clusters, the relationships previously found were assigned to the corresponding pair of clusters, and we gave them a polarity, positive or negative. For example, a claim in an article that stated that when factor A (cluster A) increases then factor B (cluster B) decreases, was assigned as a negative polarity. But if factor B increases instead, it corresponds to a positive polarity. Table 3 presents examples of causal relationships between factors, their polarities, and references.

Table 3. Examples of relationships between clusters for each article

Factor A	**Affects factor B**	**Polarity**	**Source**
Feedback	Success	+	Kricorian *et al.* [9]
Mentorship	Diversity in STEM	+	Kricorian *et al.* [9]
Economic constraints	Retention	-	Moreira *et al.* [10]
Number of URM	Environment	+	Moreira *et al.* [10]
Retention	Number of URM	+	Okahana *et al.* [11]
Student recruitment	Retention	+	Okahana *et al.* [11]
Autonomy	Engagement	+	Virtanen *et al.* [12]
Relatedness within academic communities	Sense of belonging	+	Virtanen *et al.* [12]

D. Casual Loops diagrams

To build the CLDs, we selected a factor (cluster) that had high relevance to each hypothesis, then we looked for a feedback loop, between all the possible sequences of relationships.

For the first hypothesis, associated with the relationship Advisor-Advisee, we used the cluster **Positive relationship with the supervisor** as the central factor and identified the causal relations with other factors. In [10] we found a positive causality from **Positive relationship with the supervisor** to **Persistence**, while in [12] the causalities went from **Positive relationship with supervisor** to **Engagement**, **Experienced well-being**, and **Sense of contribution**. These four factors formed a first level of factors impacted by the relationship with the supervisor. Then we looked for a second level of factors, that were impacted by the first level factors. We kept including new levels until all possible relationships were exhausted. Table 4 summarizes the relationships found for this first hypothesis. If one cluster did not impact another cluster, the search ended up for that cluster, that's the case of **Persistence** or **Experienced well-being**.

Because it looked like there was not a feedback loop that started and ended in **Positive relationship with the supervisor,** we built a partial CLD and then look for other research findings to close it if possible. First, we extracted the sequences that included more clusters. Then we reviewed the articles for the narrative of each sequence. Finally, we selected the one that had a supportive narrative to the hypothesis, showed possible connections to the central factor, and had more factors in the sequence with a direct impact on persistence. The selected sequence was: **Positive relationship with supervisor- Sense of contribution – Engagement – Self-efficacy- Success**.

Table 4. Relationships between clusters for first hypothesis

Level	Factor A	Affects factor B	Polarity	Source
Central factor	Positive relationship with the supervisor	Persistence	+	Moreira *et al.* [10] Virtanen *et al.* [12]
		Engagement	+	Virtanen *et al.* [12]
		Experienced well-being	+	Virtanen *et al.* [12]
		Sense of contribution	+	Virtanen *et al.* [12]
1	Engagement	Experienced well-being	+	Virtanen *et al.* [12]
		Persistence	+	Virtanen *et al.* [12]
		Personal Investment	+	Virtanen *et al.* [12]
		Self-efficacy	+	Virtanen *et al.* [12]
		Sense of contribution	+	Virtanen *et al.* [12]
1	Sense of contribution	Engagement	+	Virtanen *et al.* [12]
		Environment	+	Virtanen *et al.* [12]
2	Self-efficacy	Engagement	+	Virtanen *et al.* [12]
		Experienced well-being	+	Virtanen *et al.* [12]
		Motivation	+	Virtanen *et al.* [12]
		Success	+	Virtanen *et al.* [12]
2	Environment	Retention	+	Moreira *et al.* [10]
		Persistence	+	Virtanen *et al.* [12]
3	Retention	Number of URM	+	Okahana *et al.* [11]
4	Number of URM	Environment	+	Moreira *et al.* [10]
		Institutional outcomes	+	Moreira *et al.* [10], Okahana *et al.* [11]
		Economic constraints	-	Okahana *et al.* [11]
5	Economic constraints	Retention	-	Moreira *et al.* [10]

In Virtanen *et al.* [12] we found the dynamics for the first factors of this sequence. They identified experiences of doctoral students that increased their **engagement** in their Ph.D. program. They found that experiences in which the student felt a **sense of contribution** boosted the student's engagement and that these experiences could happen in different contexts, one of them being the **relationship with the supervisor**. They reported that when the supervisor shared their interest and excitement about the student's research topic, the student had a **sense of contribution** to the topic and the discussion held with the supervisor about the topic [12]. In summary, when a supervisor builds up a student and provides constructive support it conveys to the student that the work they are doing matters, which is identified as an engaging experience. As students remain **engaged**, their knowledge increases, they have new ideas and research results, and their research skills are improved. From these experiences, they get a sense of competence or **self-efficacy** [12]. The student's confidence in their capacity to attain a specific performance (**self-efficacy**) leads to better achievement or **success** [12].

The factors in the sequence that directly reinforces **Persistence** are **Positive relationship with the supervisor** and **Engagement**. A relationship with a supervisor that lacks trust, communication, and support is the main cause of students dropping their Ph.D. [10]. In addition, Virtanen et al. [12] suggest that the student's engagement in their research work is a predictor for persistence.

To close the feedback loop and create the CLD we did a purposive literature search to find causal relationships between any of the factors in the sequence and a **Positive relationship with the**

supervisor. Barnes [13] conducted a study to determine what advisors expected from their doctoral students. They identified that commitment and making progress, among others, were some of the most important expectations. Advisors expect that their advisees are committed to learning, investing in their work, and having initiative [13]. They consider that commitment is in two ways, and students must give back the commitment they demand [13]. In summary, [13] acknowledges a positive causality between **Engagement** and **Positive relationship with the supervisor.** In addition, advisors expect that their advisees advance in the doctoral program, for example by establishing and reaching objectives, and being productive. Advisors are aware that the students will complete their degree if they do continuous progress [13]. **Self-efficacy**, by our definition, includes the students' ability to have attainments, which is equivalent to the expected progress described by [13]. In conclusion, we found two causal relations between elements of the partial CLD and the central factor, which led to closing the feedback loop. The resulting CLD is presented in Figure 1.

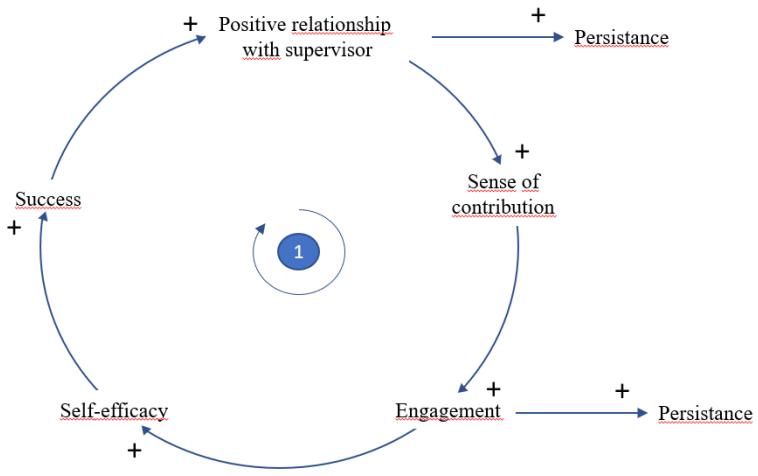

Figure 1. Causal Loop Diagram for hypothesis 1

The second hypothesis focused on the student's experience. We selected as the central factor **Sense of belonging** and found the factors and causal relations that came off the central factor. Table 5 presents the results of this search.

After following the paths through the different levels in table 5, no loop involving **Sense of belonging** as the central factor could be identified. As for hypothesis 1, we created a partial CLD using the sequence that included more factors, with at least one of them impacting **Retention,** had a logical narrative that supported hypothesis 1 and potential feedback to the central factor. The selected sequence was: **Sense of belonging – Retention – Number of URM – Environment.**

Table 5. Relationships between clusters for the second hypothesis

Level	Factor A	Affects factor B	Polarity	Source
Central factor	Sense of belonging	Persistence	+	Kricorian *et al.* [9]
		Positive perception of STEM	+	Kricorian *et al.* [9]
		Retention	+	Kricorian *et al.* [9]
		Success	+	Kricorian *et al.* [9]
		Engagement	+	Virtanen *et al.* [12]
		Experienced well-being	+	Virtanen *et al.* [12]
1	Positive perception of STEM	Retention	+	Kricorian *et al.* [9]
		Number of URM	+	Kricorian *et al.* [9]
1	Retention	Number of URM	+	Okahana *et al.* [11]
1	Success	Institutional outcomes	+	Okahana *et al.* [11]
1	Engagement	Experienced well-being	+	Virtanen *et al.* [12]
		Persistence	+	Virtanen *et al.* [12]
		Personal Investment	+	Virtanen *et al.* [12]
		Self-efficacy	+	Virtanen *et al.* [12]
		Sense of contribution	+	Virtanen *et al.* [12]
2	Number of URM	Environment	+	Moreira *et al.* [10]
		Institutional outcomes	+	Moreira *et al.* [10], Okahana *et al.* [11]
		Economic constraints	-	Okahana *et al.* [11]
2	Sense of contribution	Engagement	+	Virtanen *et al.* [12]
		Environment	+	Virtanen *et al.* [12]
2	Self-efficacy	Engagement	+	Virtanen *et al.* [12]
		Experienced well-being	+	Virtanen *et al.* [12]
		Motivation	+	Virtanen *et al.* [12]
		Success	+	Virtanen *et al.* [12]
3	Environment	Retention	+	Moreira *et al.* [10]
		Persistence	+	Virtanen *et al.* [12]
3	Economic constraints	Retention	-	Moreira *et al.* [10]

Kicorian *et al.* [9] found that there is a particularly positive causality between the **Sense of belonging** in STEM and retention rates in STEM careers for women and black students. The **Sense of belonging** is presented as influenced by the relationship with mentors, that in turn is thought to be one of the factors to leverage engagement and **Retention** to improve diversity in STEM. Additionally, Okahana *et al.* [11] identified that problems with the recruitment and **Retention** of URM students in Ph.D. programs start with the low level of completion rates at the undergraduate level. The gap extends from that point up to the graduate level, where less than 50% of undergraduates move forward to pursue a graduate degree in STEM areas [11]. In summary, increasing the sense of belonging will increase retention, which means a higher **Number of URM** students. If the **Number of URM** students increases, it increases the likelihood that students will find other individuals they identify with (in gender, ethnicity, and race). The latter is important because as suggested by Moreira *et al.* [10], URM students may find it difficult to adapt to the culture of graduate school where the population of URM students is small. Moreira *et al.* [10] highlight that community-building interventions are essential to

strengthen URM students' support. From Moreira *et al.* we can conclude that having more URM students strengthens the community and improves the **Environment** for the student.

To close the feedback loop we used the conclusions in Tinto[14]. Tinto argues that for succeeding at university and persisting to completion, students should see themselves as members of a community. This community involves fellow students, academics, and professional staff that value their membership in the community, and it is the most direct influence on the development of a **Sense of belonging**. Tinto [14] also comments that students with a strong **Sense of belonging** tend to persist because it boosts motivation and the willingness to be involved with other people, further promoting persistence.

Figure 2 presents the CLD built with the causal relationships described in the previous paragraphs. A higher sense of belonging in URM students increases their willingness to persist and complete a program, which in turn reflects on a larger number of URM graduate students and a diversification of the STEM field which in turn improves the Environment. A more inclusive environment will impact positively the **Sense of belonging.**

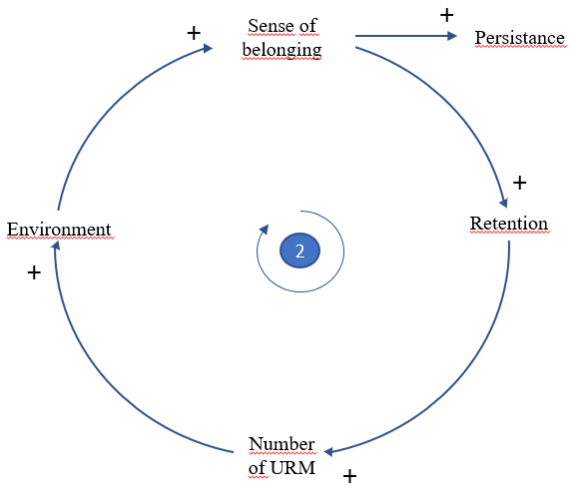

Figure 2. Causal Loop Diagram for hypothesis 2

For the third hypothesis about faculty-student interaction, we selected the factor **Relatedness with the academic community**. Following the same methodology, we built the table with the levels of relationships and explored the potential sequences for a feedback loop. An interesting finding was that the sequence meeting the criteria to create a partial CLD for the factor **Relatedness with the academic community**, was like the sequence for the first hypothesis. It included the same factors of **Sense of contribution**, **engagement**, **success,** and **self-efficacy**. This finding could be explained because we were exploring the same articles for both hypotheses, but it also suggests that a positive feedback loop that encourages persistence could be achieved through a positive relationship with the supervisor, but in case of failure of this element, it could be replaced with relatedness with the academic community. The CLD of figure 3 presents the resulting sequence.

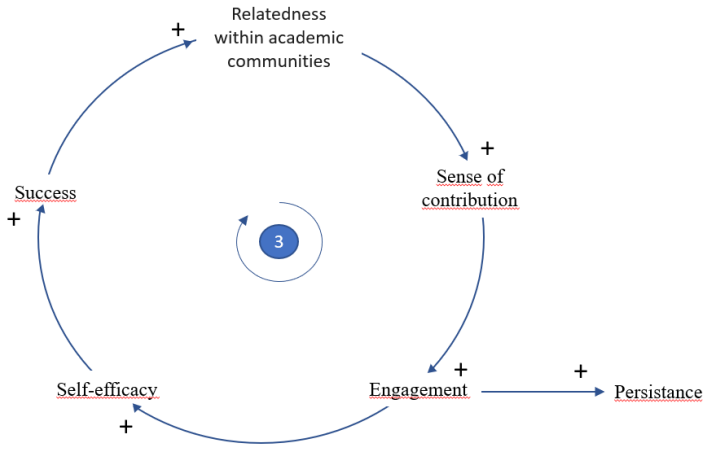

Figure 3. Causal Loop Diagram for hypothesis 3

VI. Discussion

This study aims to advance the understanding of the dynamics between factors that affect the persistence of URM students in their doctoral programs. By exploring the results of different studies, we extracted causal relations between factors and built two CLDs as the initial base for a System Dynamic Model. The first CLD provides information on how a positive relationship with the supervisor can enhance a feedback loop that involves raising the student's sense of contribution, engagement, and self-efficacy. If the feedback loop is nourished and maintained, the URM student will be more likely to persist. We found that a similar CLD can be built when replacing the positive relationship with the supervisor with relatedness with the academic community. This finding is relevant because it seems that a poor relationship with the supervisor increases the student's odds to opt out of the doctoral program, however, the situation can be shifted if there are strong ties with other members of the research community.

The second CLD informs about the importance of finding other members of the community with whom the URM student can identify in gender, race, and ethnicity. The built CLD included the number of URM students as a key factor to improve the environment for an individual. If the environment is improved, then the student will enhance the sense of belonging. If the feedback loop is maintained, the chances that a URM student persist will increase. For this loop, we also found that it is as important that students identify with peers as it is to identify with mentors.

To build the CLDs we followed the process suggested by Bronson & Jacobson [7] of finding the concepts and causal links from previous research to build the models represented in the CLDs. We brought a new element to the process by cross-referencing concepts between articles and building CLDs that included causal relations between different sources.

To build the first CLD we did a literature review to search for causal links between students' attitudes such as engagement, and self-efficacy with having a positive relationship with the

supervisor. We only found one article from 2009 that explored these connections by understanding the expectations that the advisors have from their relationship with their advisees. This suggests that although the relationship between the advisor and the advisee has been recognized as an important factor for retention, further work is warranted to explore the dynamics of the advisor's perspective and persistence.

VII. Limitations

The study presented in this paper included a limited number of articles, which in turn limited the number of factors and dynamics that we analyzed. The four articles selected were studies that focused on doctoral students, and three of them specifically on URM students. However, they provide only partial information about the complete system. For example, any of them included factors that did reference to systemic racism.

VIII. Conclusions

This paper presents the results of a work-in-progress study that aims to build a System Dynamic Model (SDM) of the persistence of URM students in doctoral programs. The first part of the study was presented in [6], in which it was conducted a literature review to find the factors that affected persistence. The second part consisted of building the initial Causal Loops Diagrams (CLD) between the factors found in [6]. In this paper, we present the methodology followed to create two major CLDs that relate directly to URM students' persistence. One of them was built around the concept of a **Positive relationship with the supervisor**, and the other around the **sense of belonging**. The methodology followed proved to be successful to construct CLDs from data from previous research and could be used in the future to continue building the CLDs and the complete SDM.

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X. References

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