

Application of Systems Engineering Analysis Methods to Examine Engineering Transfer Student  
Persistence

Natasha Leigh Smith

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in  
partial fulfillment of the requirements for the degree of

Doctor of Philosophy  
In  
Industrial and Systems Engineering

Eileen M. Van Aken, Chair  
Navid Ghaffarzadegan  
Jacob R. Grohs  
Niyousha Hosseinichimeh  
Brian M. Kleiner

December 17, 2019  
Blacksburg, VA

Keywords: systems engineering; system dynamics; systematic review; regression; engineering  
transfer student; persistence

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## **ABSTRACT**

The demand for engineering graduates in the United States continues to grow, yet the number of students entering post-secondary education is declining, and graduation rates have seen little to no change over the last several decades. Engineering transfer students are a growing population and can help meet the nation's needs, however, there is little research on the persistence of this population after they transfer to the receiving institution.

Student persistence is dependent on a complex set of interactions over time. Management systems engineering provides a framework for working with complex systems through system analysis and design, with a focus on the interactions of the system components. This research includes multiple management systems engineering analysis methods used to define and develop a systems view of engineering transfer student persistence.

This work includes a comprehensive literature review to identify factors affecting engineering transfer student persistence, an empirical analysis of an institutional dataset, and development of a simulation model to demonstrate the throughput of engineering transfer student. Findings include 34 factors identified in the literature as affecting engineering student persistence. A review of the literature also highlighted two important gaps in the literature, including a focus on post-transfer success almost exclusively in the first post-transfer year and a significant interest in vertical transfer students, with little consideration given to lateral transfer students. The empirical analysis addressed the gaps found in the literature. Vertical and lateral engineering transfer students were found to experience different levels of transfer shock which also impacts their 4-year graduation rates. The analysis also found transfer shock was not unique to the first post-transfer term, it was also present in the second and third post-transfer terms, and reframed as transfer adjustment. The simulation model uncovers leaving patterns of engineering transfer students which include the students leaving engineering in the second year, as well as those graduating with an engineering degree in the third year.

Overall this research identifies explicit factors that affect engineering transfer student persistence and suggests a new systems engineering approach for understanding student persistence and how institutions can affect change.

# Application of Systems Engineering Analysis Methods to Examine Engineering Transfer Student Persistence

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## **GENERAL AUDIENCE ABSTRACT**

The United States continues to need more students graduating with a bachelor's degree in engineering. To meet this demand, higher education institutions are investing more time to learn how to increase the number of engineering graduates. One method is through increasing the number of students that start and finish an engineering degree. There are two types of students enrolled in engineering degrees. The first type are students that begin a bachelor's degree at a 4-year institution after completion of high school; these students are known as first-time, full-time (FTFT). The second type of student are transfer students who begin at one institution and move to another. The transfer students could have started at another 4-year institution, or they may begin at a 2-year community college. There has been a significant focus on increasing the number of FTFT students starting and finishing an engineering degree. However, there is little research on engineering transfer students and their ability to finish an engineering degree after transferring.

The throughput of a student in the higher education system is a complex set of interaction over time that results in either the student earning a degree or not earning a degree. Systems engineering is a field of engineering that focuses on the design of complex systems and is well-suited to be applied to better understanding student throughput. The purpose of this research is to introduce systems engineering methodologies to determine what affects the persistence of engineering transfer students, i.e., finishing an engineering degree. The research findings indicate more attention should be given to engineering transfer students in their second year of enrollment. Findings also suggest that engineering transfer students should not be considered as one population. There are several types of engineering transfer students and they each have different experiences during their transfer process which influence their ability to finish an engineering degree.

## **Acknowledgement**

I am incredibly thankful for the many individuals who have supported and encouraged me throughout this journey. It is your belief in me that has been my stronghold when I wanted to give up. To begin, I would like to thank Dr. Stephanie Adams who so nonchalantly said to me, “Why not a PhD?”. These words have continued to propel me forward, and I am forever indebted to you, thank you for believing in me. To my advisor, Dr. Eileen Van Aken, who gave me the freedom to find and pursue the intersection of my interests. Even as your responsibilities increased when you became the department head, you maintained your commitment to my success, thank you for believing in me. To my committee, Dr. Jacob Grohs, Dr. Navid Ghaffarzadegan, Dr. Niyousha Hosseinichimeh, and Dr. Brian Kleiner, who brought a variety of backgrounds and expertise, your willingness to see me through this process is greatly appreciated. You’ve pushed me, but also always been there when I needed help, thank you for believing in me.

To my amazing colleagues in the Department of Engineering Education, your constant requests for updates and words of encouragement provided a level of accountability and motivation that was a large factor in my continued persistence, thank you for believing in me. To Dr. Marlena Lester, my colleague and best friend, this would not have been possible without you. You make me a better person and ensure that I never settle, thank you for believing in me.

To my husband, you have quietly encouraged me for so many years, and have been so understanding of the countless hours I have spent in pursuit of this goal. I know the sacrifices you have made, and appreciate your consistent and constant encouragement, thank you for believing in me. And finally, to my precious daughters. For most of your life, you’ve understood that I am still in school, it seemed so normal to you that I was doing homework when you woke up and wandered around the house to find my study spot for that night. I will never forget when I told you I was Dr. Mommy and you inhaled sharply and looked at me with the biggest smile and said, “Mommy, I’m so proud of you.” You are the light of my life, thank you for believing in me.

## Table of Contents

<b>ABSTRACT</b> .....	ii
<b>GENERAL AUDIENCE ABSTRACT</b> .....	iii
<b>Acknowledgement</b> .....	iv
<b>Table of Contents</b> .....	v
<b>List of Figures</b> .....	viii
<b>List of Tables</b> .....	ix
<b>Attribution</b> .....	x
Chapter 2 (Manuscript 1: How System Dynamics can be an Effective Modeling Method to Understand Engineering Transfer Student Persistence).....	x
Chapter 4 (Manuscript 2: Systematic Literature Review of Persistence of Engineering Transfer Students).....	x
Chapter 5 (Manuscript 3: Comparison of Transfer Shock and Graduation Rates Across Engineering Transfer Student Populations).....	xi
Chapter 6 (Manuscript 4: Developing a Simulation Model to Examine Persistence of Engineering Transfer Students).....	xi
<b>Chapter 1</b> Introduction.....	1
1.1 Background.....	3
1.2 Research Problem.....	4
1.3 Research Objectives.....	5
1.4 Expected Contributions.....	6
1.5 Overview of Dissertation.....	7
<b>Chapter 2</b> Initial Investigation (Manuscript 1: How System Dynamics can be an Effective Modeling Method to Understand Engineering Transfer Student Persistence).....	9
2.1 Manuscript copyright transfer agreement.....	9
2.2 Abstract.....	9
2.3 Introduction.....	10
2.4 Literature Review.....	12
2.5 Student Persistence Models.....	14
2.6 Using System Dynamics.....	16
2.7 Reference Modes.....	17
2.8 Causal Loop Diagram.....	20
2.9 Conclusions.....	22
References.....	23
<b>Chapter 3</b> Research Methodology Overview.....	28
3.1 Summary of Approach.....	28
3.2 Research Framing and Synthesis.....	30
3.4 Institutional Analysis.....	31
3.4 Model Development.....	32
<b>Chapter 4</b> Systematic Literature Review and Thematic Synthesis (Manuscript 2: Systematic Literature Review of Persistence of Engineering Transfer Students).....	34
4.1 Abstract.....	34
4.2 Introduction.....	35
4.3 Methods.....	37
4.3.1 Search Strategy Protocol.....	38

4.3.2 Selection Process .....	40
4.3.3 Applying Exclusion Criteria .....	40
4.3.4 Limitations .....	41
4.3.5 Analysis .....	42
4.4 Findings .....	43
4.4.1 Question 1: Factors identified as affecting engineering transfer student persistence...	43
4.4.2 Question 2: Frameworks used to understand engineering transfer student persistence	51
4.5 Discussion .....	56
4.6 Conclusions .....	59
References .....	60
Appendix A .....	77
Appendix B .....	79
<b>Chapter 5 Institutional Analysis (Manuscript 3: Comparison of Transfer Shock and Graduation Rates Across Engineering Transfer Student Populations)</b> .....	82
5.1 Abstract .....	82
5.2 Introduction .....	83
5.3 Background .....	84
5.4 Research Objectives .....	87
5.5 Methods .....	88
5.6 Results .....	91
5.6.1 Descriptive Statistics .....	91
5.6.2 Research Questions .....	93
5.6.3 Limitations .....	102
5.7 Discussion .....	103
5.7.1 Transfer Adjustment .....	104
5.7.2 Engineering Transfer Student Sub-Groups .....	105
5.7.3 Transfer Adjustment Affects Graduation .....	105
5.7.4 Transfer Adjustment Scale .....	106
5.8 Conclusion .....	107
5.9 Acknowledgements .....	108
References .....	108
<b>Chapter 6 System Dynamics Model Development and Testing (Manuscript 4: Developing a Simulation Model to Examine Persistence of Engineering Transfer Students)</b> .....	117
6.1 Abstract .....	117
6.2 Background .....	118
6.3 Research Objectives and Approach .....	119
6.4 Methods .....	121
6.4.1 Model Development .....	122
6.4.2 Data .....	122
6.4.3 Model Overview .....	123
6.4.3 Model Testing .....	127
6.5 Results and Discussion .....	129
6.5.1 Limitations .....	135
6.6 Conclusions .....	135
6.7 Acknowledgements .....	137
References .....	137

<b>Chapter 7</b> Conclusions.....	142
7.1 Comparing the Synthesized Results to the Institutional Findings .....	142
7.2 Comparing the Synthesized Results and Institutional Findings to the System Dynamics Model .....	145
7.3 Contributions.....	146
7.4 Implications for practice.....	148
7.5 Limitations .....	149
7.6 Future Work .....	150
<b>References</b> .....	152

## List of Figures

Figure 1.1 Total U.S. Public and Private High School Graduates (Actual and Projected) 1979 to 2032 (WICHE, 2016).....	2
Figure 2.1 Enrollment and Transfer Student Breakdown Across Higher Education.....	11
Figure 2.2 Student Retention Integrated Model (Cabrera, Nora, and Castaneda, 1993) .....	15
Figure 2.3 Retention Rates for Institution and Engineering Transfer Students .....	19
Figure 2.4 Graduation Rates for Institution and Engineering Transfer Students .....	19
Figure 2.5 Preliminary Causal Loop Diagram of Transfer Student Retention .....	21
Figure 3.1 Research Methodology .....	29
Figure 3.2 Stages of SD Modeling (Sterman, 2000).....	32
Figure 4.1 Overview of review process based on PRISMA guidelines (Moher et al., 2009).....	41
Figure 4.2 Categories and Factors Identified from the Literature .....	44
Figure 4.3 Literature-based Conceptual Framework of Engineering Transfer Student Persistence .....	55
Figure 5.1 Box Plots of Transfer GPA and Term GPAs by Student Type .....	93
Figure 6.1 Engineering Transfer Student Graduation Rates at Institution Alpha.....	120
Figure 6.2 Aging Chain Component of SD Model.....	124
Figure 6.3 Historical and Simulation Results. Note: x-axis in figures a-d is cohort. ....	128
Figure 6.4 Effect of Changing the Leaving Rate in the Second PTY.....	130
Figure 6.5 Leaving Rate in the Second Post-Transfer Year at Institution Alpha .....	131
Figure 6.6 Categories and Factors Identified from the Literature (Authors, Under Review).....	132
Figure 6.7 Graduation Rate in the Third Post-Transfer Year .....	133

## List of Tables

Table 4.1 Search Concepts and Terms.....	39
Table 4.2 Initial Search Results .....	39
Table 4.3 Identified Frameworks .....	51
Table 4.4 Coding Framework .....	77
Table 4.5 Factors Impacting Engineering Transfer Student Persistence .....	79
Table 5.1. Common Factors of Engineering Transfer Student Persistence (Authors, Under Review).....	85
Table 5.2. Transfer Student Types .....	88
Table 5.3 Transfer Shock Measurements (TSM).....	90
Table 5.4. Normality Tests.....	91
Table 5.5 Student Demographics .....	92
Table 5.6. Transfer Shock Measurements Mean and Standard Deviations .....	94
Table 5.7 Transfer Shock Measurements Mean and Standard Deviation (Std. Dev.) .....	95
Table 5.8 Persistence Rates Across Transfer Student Types .....	97
Table 5.9 Logistic Regression Results (Odds Ratio) for Graduated Engineering in Four Years .	98
Table 5.10 Mean and Standard Deviation of Transfer Shock Categories by Level .....	100
Table 5.11 Number and Percent of Students in Each Level .....	100
Table 5.12 Graduation Rates by Highest Level Category .....	102
Table 6.1 MAPE Values (Number of Graduates, Students Leaving, and Continuing Enrollment) .....	129

## **Attribution**

### Chapter 2 (Manuscript 1: How System Dynamics can be an Effective Modeling Method to Understand Engineering Transfer Student Persistence)

This manuscript provides a high-level systems engineering lens on engineering transfer student persistence. The work in this manuscript demonstrates the complexity of student persistence and why traditional persistence frameworks do not capturing the full system. This is an initial review that helps set up the remainder of the dissertation work which includes identifying a comprehensive list of factors impacting engineering transfer student persistence, analyzing a longitudinal institutional dataset, and developing and testing a system dynamics model. This research was conducted by Natasha L. Smith under supervision of research advisors. The manuscript was written by Natasha L. Smith who is the sole author. The manuscript was submitted to the American Society for Engineering Management 2018 International Annual Conference in July 2018. The manuscript was accepted in August 2018 and presented at the conference in October 2018.

### Chapter 4 (Manuscript 2: Systematic Literature Review of Persistence of Engineering Transfer Students)

This manuscript presents the results of a systematic literature review on this research topic. Over 2,000 publications were evaluated and 82 were identified for the final publication set. The work in this manuscript finds 34 factors that were identified as affecting engineering transfer student persistence. The findings included gaps in the literature that were used to guide the research in the institutional analysis. This research was conducted by Natasha L. Smith under supervision of research advisors. Authors for this manuscript include Natasha L. Smith and Eileen M. Van Aken.

The lead author for this manuscript was Natasha L. Smith. The manuscript was submitted to the Journal of Engineering Education in April 2019, and has been returned for minor revisions which are due in February, 2020.

Chapter 5 (Manuscript 3: Comparison of Transfer Shock and Graduation Rates Across Engineering Transfer Student Populations)

This manuscript presents the results of a quantitative analysis of a single-institution dataset. The work in this manuscript identifies differences in the transition experience of engineering transfer student sub-groups, as well as differences in graduation rates. Findings from this work confirm a need to consider the post-transfer academics of engineering transfer student past the first post-transfer term, which informs the simulation model development. This research was conducted by Natasha L. Smith under supervision of research advisors. Authors for this manuscript include Natasha L. Smith, Jacob R. Grohs, and Eileen M. Van Aken. The lead author for this manuscript was Natasha L. Smith. The manuscript is in preparation for submission to the Journal of Engineering Education.

Chapter 6 (Manuscript 4: Developing a Simulation Model to Examine Persistence of Engineering Transfer Students)

This manuscript presents the results of the system dynamics model simulation. The work in this manuscript identifies when engineering transfer students leave engineering within the four years, and provides insights into how institutions can affect the leaving patterns. Findings from this work confirmed the need to further investigate the students' academic performance beyond the first post-transfer year. This research was conducted by Natasha L. Smith under supervision of research advisors. Authors for this manuscript include Natasha L. Smith, Navid Ghaffarzadegan, and Eileen

M. Van Aken, and. The lead author for this manuscript was Natasha L. Smith. The manuscript is in preparation for submission to System Dynamics Review.

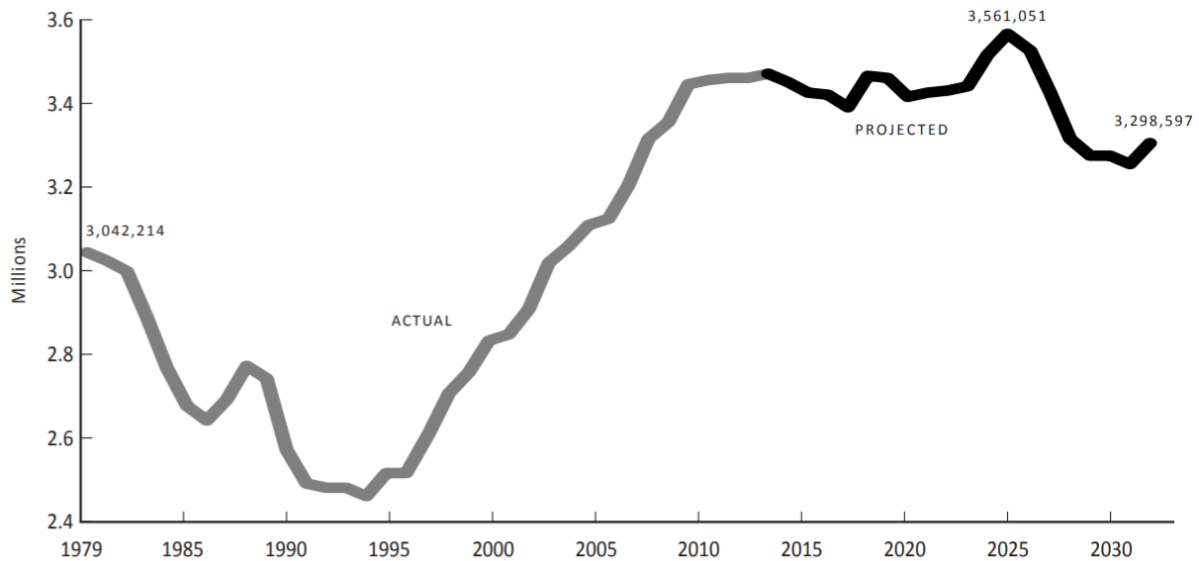
# Chapter 1

## Introduction

Persistence is formally defined by Pascarella, Smart, and Ethington (1986) as actively working toward a bachelor's degree within a nine-year period. Higher education institutions have long been studying student persistence; the earliest studies in the United States (U.S.) were in the 1930's (Berger & Lyon, 2005). Traditionally, studies on student persistence focus on first-time, full-time (FTFT) students, which describe students' first enrollment at a post-secondary institution on a full-time basis. However, despite nearly a century of trying to understand FTFT student persistence, their average six-year graduation rate is just under 60% (National Center for Education Statistics, 2019). The average six-year graduation rate for FTFT engineering students is also just under 60% (ASEE, 2016).

The President's Council of Advisors on Science and Technology (PCAST) (2012) indicated the U.S. would need one million more graduates in the science, technology, engineering, and math fields over the next decade. A more recent congressional report confirmed a continued need for additional engineers (Sargent, 2017). However, the Western Interstate Commission on Higher Education (WICHE) forecasts an overall decrease in high school graduates over the next 20 years, as shown in Figure 1.1 (WICHE, 2016).

Figure 1.1 Total U.S. Public and Private High School Graduates (Actual and Projected) 1979 to 2032 (WICHE, 2016)



As the need for engineering graduates continues to increase and the number of students graduating from high school decreases, the U.S. faces a problem of more outputs needed with fewer inputs available. Given these constraints, focus must be given to the process of graduating students in an effort to increase persistence of the entering engineering students. Researchers, educators, and administrators have long focused on FTFT engineering student persistence to help meet this need for additional engineers. However, minimal research has been conducted on the post-transfer success of engineering transfer students and little is known about their persistence. Transfer students are defined as those attending more than one institution on their route to a bachelor's degree, and are a growing student population in the U.S. (Brawner & Mobley, 2016; Habley, Bloom, & Robbins, 2012). While researchers should continue to focus on FTFT engineering students, engineering transfer students can also help meet the nation's demand for engineering graduates.

## 1.1 Background

Transfer students may be vertical transfers, who move from a two-year institution to a four-year institution, or they may be lateral transfers, who move from one four-year institution to another four-year institution. Engineering transfer students are a growing population and one that can help achieve the nation's completion goals (Glynn, 2019).

There is a limited amount of longitudinal data on transfer students. The National Center for Education Statistics (NCES) and the National Student Clearinghouse Research Center (NCSRC) have recently begun reporting on transfer students and through their reporting we can begin to gain an understanding of how many transfer students exist in the current U.S. undergraduate educational system. Additionally, the ASEE has recently begun collecting national level data which will provide benchmarks for researchers and practitioners as they begin to focus specifically on engineering transfer students.

There has been significant research on engineering persistence. However, much of the engineering persistence literature focuses on the persistence of FTFT students (Brawner & Mobley, 2016; Mobley, Brawner, & Long, 2014; Sullivan de Cohen, Barna, Orr, Long, & Ohland, 2012; Tobolowsky & Cox, 2012). Additionally, most literature focuses on vertical in-state transfer students, which are those transferring from a two-year institution to a four-year institution within the same state (Tobolowsky & Cox, 2012). A recent report from NCSRC indicates that vertical transfers are no longer the predominant transfer pathway and lateral transfers are growing at a faster rate (Shapiro, Dundar, Huie, Wakhungu, Bhimdiwali, Nathan, & Youngsik, 2018).

A common finding in the literature is the existence of transfer shock, which refers to a decrease in grade point average (GPA) that students commonly experience when transitioning to

a new institution (Hills, 1965). The idea of transfer shock originates from culture shock which describes the interaction between one's existing behavior and habits within a new environment (Zapf, 1991; Ivins, Copenhaver, & Koclanes, 2017). This is an important concept in understanding attrition of engineering transfer students as it has been found to be a predictor of students being placed on academic probation in their first term, as well as leaving the university (Graham & Dallam, 1986; Glass & Harrington, 2002; Ishitani, 2008; Lakin & Cardenas Elliott, 2016). Additionally, Lakin and Cardenas Elliott (2016) posit students in engineering experience the largest degree of transfer shock. Understanding engineering transfer students, both vertical and lateral, and how to improve their persistence within engineering can provide additional pathways to meet the nation's goals and needs of engineering graduates.

Persistence is dependent on a complex set of interactions over time (Cabrera, Nora, & Castaneda, 1993). This idea is further supported by Ghaffarzagdegan, Larson, and Hawley (2017) who define education as a non-linear, complex system, and argue a systems approach is more appropriate than current methodologies being used. The main quantitative methods used when studying student persistence assume linearity and include multiple regression, Pearson chi-square analysis, analysis of a variance (ANOVA), as well as structural equation modeling. However, these methods work under the assumption of linearity. While they can provide insight into significance and relationships of the variables being studied, they still lack the ability to see the full dynamics of the system.

## 1.2 Research Problem

Despite decades of research and efforts, college completion rates have minimally changed. Persistence studies in engineering have focused on FTFT students, leaving a dearth of research on

engineering transfer student persistence. To begin understanding this population and how persistence can be increased, a comprehensive list of factors affecting their persistence is needed. In addition, it is important to distinguish between vertical transfer students and lateral transfers students, as they will have inherently different pre-transfer experiences, as well as reasons or motivations for transferring that will shape their post-transfer experience. Finally, there is a need to introduce a new perspective to persistence studies that can consider the non-linearity of the system and provide a better lens to view the interactions with the system and how they impact the overall persistence rate.

### 1.3 Research Objectives

The purpose of this research is to provide recommendations on how to improve persistence rates in engineering transfer students. To achieve this aim, this research has three primary objectives:

- 1) comprehensively synthesize the existing literature to determine the range of factors that affect transfer student persistence;
- 2) identify differences in the transition experience and graduation rates of vertical and lateral engineering transfer students; and
- 3) develop and test a system dynamics model aimed at understanding the behavior of the system and how institutions can affect persistence of this population.

The first objective was completed through a comprehensive systematic literature review and thematic analysis. A comprehensive list of factors affecting engineering transfer student persistence was developed, which represented all that were discussed in the final publication set. An iterative synthesis of those factors was also completed to reduce the factors into categories,

and to determine themes that can more broadly describe what affects engineering transfer student persistence. The second objective was completed through a quantitative analysis using several statistical analysis methods, including chi-square testing, analysis of a variance, and logistic regression. These methods were used to identify statistical differences in the academic performance and ultimate graduation of multiple sub-groups of engineering transfer students. The third objective was completed using system dynamics software to develop and test a simulation model that represented the movement of students from admissions to graduation and what levers could be used to affect that movement.

#### 1.4 Expected Contributions

This research is focused on understanding how institutions can improve engineering transfer student persistence, and will result in several contributions. To accomplish this research, methodologies commonly used in management systems engineering were applied, including a systematic literature review and a system dynamics simulation model. Findings from the systematic literature review provided a comprehensive list of factors affecting engineering transfer student persistence. The list of factors was important for identifying gaps in the literature, as well as informing future empirical studies. This research also reviewed the persistence frameworks that are commonly used to understand engineering transfer student persistence, and identified how they can be updated to consider the unique background and experience of engineering transfer students. An empirical analysis was also completed to address the gaps in the literature, as well as test factors that were identified in the SLR. The system dynamics model provided insight into how institutions can affect change in persistence of their engineering transfer students. Overall, this research provides important directions for academic practitioners as they seek to develop more

strategically-designed services and programming. It also provides future research directions for engineering education and enrollment management fields as scholars in these fields seek to better understand engineering transfer students. Additionally, this research introduces management systems engineering as an appropriate framework to address student persistence as complex system.

### 1.5 Overview of Dissertation

This dissertation was developed in a manuscript style. To account for each manuscript, while also providing the elements of a traditional dissertation, there are four manuscripts supported by introduction, methodology, and conclusion chapters. An attribution section has also been added at the beginning of the dissertation to provide a summary of each manuscript, including any co-authors, as well as the publication information.

Chapter 1 provides a background and details on the research problem, as well as research objectives, expected contributions, and an overview of the dissertation document. Chapter 2 presents Manuscript 1. The purpose of this manuscript is to highlight how systems engineering, specifically systems dynamics, can be used to include success factors of this student population and demonstrate the effects of feedback loops on the behavior of the system. A causal loop (CLD) is presented as an adaption of Cabrera, Nora, and Castaneda's (1993) student integrated model, and provides a means to view the interactions between factors, further demonstrating this is a complex, non-linear system.

Chapter 3 details the overall methodology for this dissertation. To identify the full range of factors influencing engineering transfer student persistence found in previous literature, a systematic literature review (SLR) methodology was selected. A thematic analysis was selected to synthesize the findings in the publications identified in the SLR. This enabled a comprehensive

understanding of the existing literature which is important for building a robust system dynamics model. A quantitative analysis was completed using a 10-year data set from a single institution. This step included several statistical tests and was necessary to complete an empirical analysis of recommendations from the first and second phases of research. Lastly, a system dynamics methodology was selected to develop a non-linear representation of engineering transfer student persistence and allow for complex interactions between the identified factors. This final phase used findings from the previous research phases to set the model boundary and provide initial parameter estimates.

The next three chapters are the manuscripts pertaining to each research phase. Chapter 4 presents Manuscript 2 which details the findings of the SLR. Chapter 5 presents Manuscript 3 which details the findings of the quantitative analysis. Chapter 6 presents Manuscript 4 which details the system dynamics model and provides final recommendations for improving engineering transfer student persistence. Chapter 7 follows with a summary of all findings from the four manuscripts, contributions of this work, and future research areas. A full list of all references is also provided after Chapter 7.

## Chapter 2

### Initial Investigation

(Manuscript 1: How System Dynamics can be an Effective Modeling Method to Understand Engineering Transfer Student Persistence)

#### 2.1 Manuscript copyright transfer agreement

This manuscript was submitted to the American Society for Engineering Management 2018 International Annual Conference in July 2018. The manuscript was accepted in August 2018 and presented at the conference in October 2018. Specific information on author attribution is provided in the Attribution section. Those interested in citing any information from this manuscript should use the following citation:

Smith, N. (2018). How system dynamics can be an effective modeling method to understand engineering transfer student persistence. *2018 American Society for Engineering Management (ASEM) International Annual Conference Proceedings*. Coeur d'Alene, ID.

#### 2.2 Abstract

As we work to meet the demands of a more diverse engineering workforce, the transfer student population becomes an important piece of that conversation due to their rich diversity that includes underrepresented minorities and first-generation students. Research indicates transfer students arrive with pre-existing characteristics that impact their persistence rates at a four-year institution, which is generally less than that of their native peers. Researchers also affirm the responsibility of institutions to provide the necessary framework and support to help this population be successful. However, as institutions create programming and set forth policies, they are often doing so non-holistically, which results in counter-intuitive outcomes that are further preventing the success of

engineering transfer students. As the transfer educational pathway continues to grow, further research is needed to identify effective ways to increase their persistence. The purpose of this paper is to discuss how system dynamics can be an effective tool to more fully understand the process undergraduate engineering transfer students go through, while considering the uniqueness of this population and the various needs they may have.

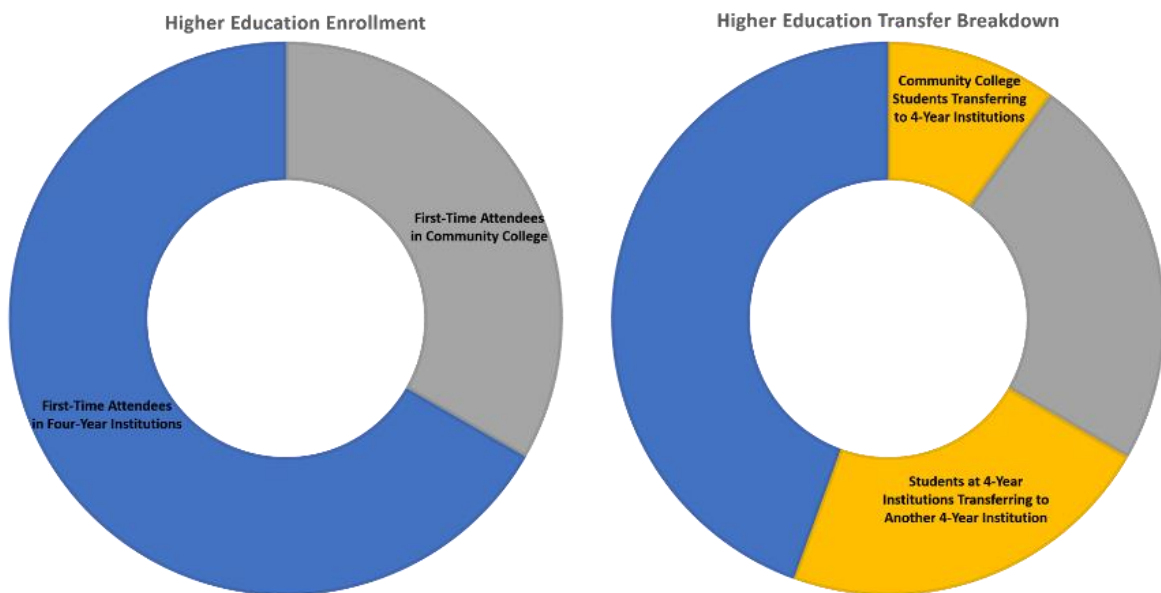
### 2.3 Introduction

For this research a transfer student is defined as a student that begins at one institution and leaves that institution to attend as a full-time student at another institution in their pursuit of a bachelor's degree. Transfer students may be vertical transfers, who move from a two-year institution to a four-year institution, or they may be lateral transfers, who move from one four-year institution to another four-year institution. Persistence is defined by Pascarella, Smart, and Ethington (1986) as actively working toward a bachelor's degree within a nine-year period.

The National Center for Education Statistics (NCES) and the National Student Clearinghouse Research Center (NCSRC) have recently begun reporting on transfer students and through their reporting we can begin to gain an understanding of how many transfer students exist in the current U.S. undergraduate student cohorts. In terms of vertical transfer, students moving from a community college to a four-year institution, reports show approximately one-third of first-time freshmen are community college attendees (Snyder, de Brey, & Dillow, 2016), and just over 30% of students attending a community college will transfer to a four-year institution (Shapiro, Dundar, Huie, Wakhungu, Yuan, Nathan, & Hwang, 2017). Additionally, more than one-third of students attending a four-year public institution transferred to another institution, known as a lateral transfer (Snyder, de Brey, & Dillow, 2016). This data is represented in Figure 2.1 and shows

transfer students make up a significant share of students attending a higher education institution. Additionally, from 2014 to 2016, the United States (U.S.) experienced a 5% increase in transfer student applications, further demonstrating the number of students following these pathways continues to increase (Clinedinst and Koranteng, 2017).

Figure 2.1 Enrollment and Transfer Student Breakdown Across Higher Education



In 2010, President Barack Obama issued a College Completion Goal for the year 2020 to increase the U.S. college degree completion attainment rate from 40% to 60% by increasing access through improved affordability, fostering institutional quality with accountability and transparency, and increasing completion rates (Kanter, Ochoa, Nassif, & Chong, 2011). The Georgetown University Center on Education and Workforce (2013) reports that by 2020, 65% of all jobs in the U.S. will require more than a high school diploma, up from 28% in 1973, and the number of high school graduates over the next 7 to 10 years is expected to be less or about the

same (WICHE, 2016). Fewer high school graduates, combined with a higher percentage of those graduates needing a post-secondary education, indicates the continued necessity of higher education institutions to increase access and see students through graduation. Additionally, the President's Council of Advisors on Science and Technology submitted a report which concluded the U.S. would need one million more science, technology, engineering, and math (STEM) professionals over the next decade to remain competitive (PCAST, 2012).

These directives have led to an increased focus on recruitment and completion rates of engineering students specifically. With transfer students making up a significant share of post-secondary education enrollment, research must be conducted on understanding and increasing engineering transfer student persistence as the U.S. strives to meet the goals set forth.

## 2.4 Literature Review

A review of the literature on transfer student persistence uncovers a topic that has not been richly studied, with the studies of engineering transfer students specifically being even more scarce. The existing literature paints a picture of an ill-understood student population that is rapidly growing.

Early researchers focused on how student characteristics impacted transfer student persistence, with the majority of findings indicating characteristics such as gender, race/ethnicity, and the number of transfer credits as the most influential variables impacting transfer student persistence (D'Amico, Dika, Elling, Algozzine, & Ginn, 2013). More recently, researchers have begun to look at institutional variables and how they might impact transfer student persistence. Findings from these studies shows variables such as campus engagement, academic advising, and mentoring have a correlation to transfer student persistence, however the impacts depend on

student's active participation in those variables (Jackson & Laanan, 2015; Ivins, Copenhaver, & Koclanes, 2017).

The existing research also varies in its findings with some suggesting these students persist at lower rates than their non-transfer peers (Ishitani, 2008; Sullivan, de Cohen, Barna, Orr, Long, Ohland, 2012; Ivins, Copenhaver, & Koclanes, 2017), and others find they perform similarly or slightly better (Holahan, Green, & Kelley, 1983; Carlan & Byxbe, 2000; Glass & Harrington, 2002). Additionally, the literature primarily focuses on students completing a vertical transfer (Tobolowsky & Cox, 2012), with little regard given to those completing a lateral transfer.

A concept that appears in all studies of transfer students is transfer shock. Transfer shock refers to a drop in GPA that transfer students commonly experience when transitioning to a new institution (Hills, 1965). Researchers show a correlation between transfer shock and transfer students on academic probation after their first semester (Graham & Dallam, 1986; Lakin & Cardenas Elliott, 2016), which is a strong predictor of transfer students leaving the institution before graduation (Ishitani, 2008, Glass & Harrington, 2002). Additionally, Lakin and Cardenas Elliott (2016) posit students in engineering experience the largest degree of transfer shock.

Due to the consistent findings of the existence of transfer shock and its impact on transfer student persistence, further understanding of this phenomenon is necessary to advance the research of transfer students and their persistence (Lakin & Cardenas Elliott, 2016). These findings are the basis for the remainder of this paper which discusses the shortcomings of the existing student persistence models, as they relate to transfer students, and introduces system dynamics as a more effective method for understanding this population of students.

## 2.5 Student Persistence Models

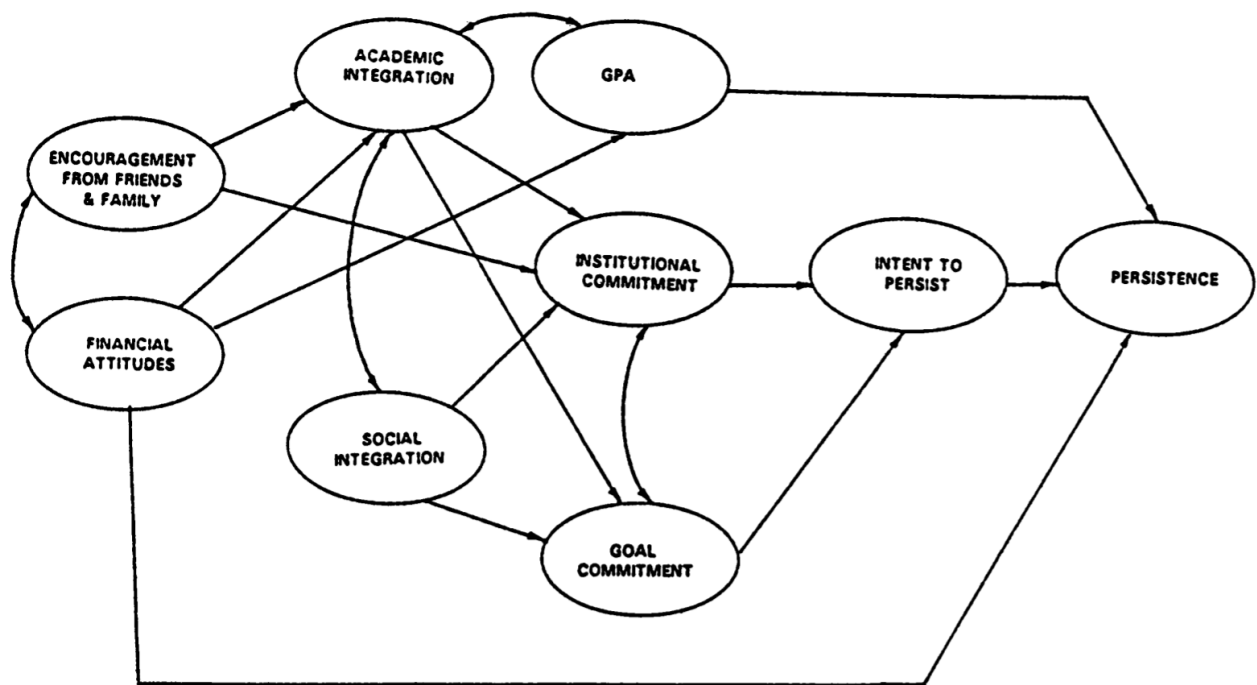
Student persistence models have been developed based on traditional first-time, full-time students (Bean & Metzner, 1986; Braxton & Lee, 2005), and do not include the study of non-traditional students. The one deviation from this was Bean and Metzner's (1986) model on non-traditional undergraduate student attrition that focused on commuter students. However, there are no student persistence frameworks that attempt to understand transfer students, and the current theoretical frameworks do not account for transfer shock.

Despite its underlying assumption of traditional (non-transfer) students and exclusion of transfer shock, Tinto's (1975) model is most often used as the framework for studies on transfer student persistence. In Tinto's more recent institutional departure model, he breaks the model into five themes: pre-entry attributes, goals/commitments, institutional experiences, integration, and outcome. Important limitations to this framework as it relates to transfer students is the focus on high school experiences as part of the pre-entry characteristics and no direct relationship between academic performance and goals/commitments.

Admissions criteria for transfer students exclude high school evaluations and SAT scores (D'Amico, Dika, Elling, Algozzine, & Ginn, 2013), therefore, the pre-entry characteristics related to high school experiences are not captured for this population and cannot be used to predict transfer student persistence. Rather, the sending institution type, the number of transfer credits, and the transfer GPA are discussed as more appropriate variables to use towards understanding transfer student persistence (Hills, 1965; Ishitani, 2008; Clinedinst & Koranteng, 2017), but are not included in Tinto's model. Additionally, when a transfer student's GPA drops, that student is likely to have a lower commitment to their major (Lakin & Cardenas Elliott, 2016) which provides a link from academic performance and goals/commitments.

Figure 2.2 demonstrates Cabrera, Nora, and Castaneda's (1993) student retention integrated model that merged Tinto's (1975) student departure model with Bean's (1980) student attrition model. The result is a framework that is more malleable and has a greater focus on relationships across multiple variables.

Figure 2.2 Student Retention Integrated Model (Cabrera, Nora, and Castaneda, 1993)



There is a wide diversity present in engineering transfer students, which indicates there is not a universal methodology (Tobolowsky & Cox, 2012). Researchers most heavily focus on students moving from a community college to a four-year institution (Tobolowsky & Cox, 2012), typically within the same state, despite Adelman (2005) showing this is no longer the predominant transfer pathway. Additionally, previous research indicates the number of credits a transfer student transfers to the receiving institution has an impact on their persistence. However, most bodies of

research do not categorize the community college transfer student population into those who attended for one year or two years, which could be used as a distinction between those that earn an associate degree and those that do not. Aggregating all transfer students over-generalizes assumptions about the population and discounts differing experiences across the various types of transfer students.

Li, Swaminathan, and Tang (2009) indicate the most utilized methods to understand student persistence includes of stepwise/hierarchical multiple regression, covariate adjustment, exploratory factory analysis, discriminate analysis, and classification trees, which all assume linearity. However, student persistence is the result of a complex set of interactions over time; this notion is central to widely accepted student persistence models (Cabrera, Nora, & Castaneda, 1993). This realization led to Ishitani (2008) using event history modeling. While this was important step to understanding transfer student persistence, this method still lacks the ability to see the full dynamics of a system, including feedback loops and delays that can lead to unintended consequences. Ghaffarzadegan, Larson, and Hawley (2017) discuss education as a complex, non-linear system which often overreacts to policy changes that can result in unintended consequences that are detrimental to the system. They call for a systems approach to understand the system complexities and how feedback loops, delays, and nonlinearity results in counterintuitive outcomes.

## 2.6 Using System Dynamics

System dynamics is a framework used in systems thinking, which is the ability to see the world as a complex system, where everything is connected and a change in one variable leads to a change somewhere else in the system (Sterman, 2000). When faced with nonlinearity and the need to

understand and solve these complex systems, Boeing (2016) indicated the human capacity to make decisions is greatly reduced as these types of systems are often chaotic and unpredictable, and can produce counterintuitive behavior. This capacity reduction leads to a selective perception of information that does not represent the entirety of the system (Hogarth, 1987). The selective perception comes from our mental models and this impacts what we think are important and useful, and can often lead to confusion between causality and correlation (Sterman, 2000). Grounded in the theory of nonlinear theory and feedback control, system dynamics is a means to enhance learning in a complex system, with consideration given to time delays, side effects, and feedback (Sterman, 2000).

There are three basic types behaviors of a dynamic system, with each developing from their feedback structures: growth indicates a positive feedback loop, goal seeking indicates a negative feedback loop, and oscillations indicate a negative feedback loop with time delays (Sterman, 2000).

## 2.7 Reference Modes

Reference modes are graphs used to show a pattern of behavior over time (Sterman, 2000). This is an important function of system dynamics as it provides a method to see a problem over time and can provide insight into how it began and how it might continue. Seeing the reference modes can also help form more long-term goals for how to approach a problem to provide the optimal solution for the given behavior patterns. To develop a reference mode, a time horizon is necessary. The time horizon is the amount of time you will be looking at the behavior of a problem. Determining the correct timeline is an important part of the reference mode as too short of a time

horizon can lead to misunderstandings of the problem and its behavior due to long time delays within feedback loops (Sterman, 2000).

The only national longitudinal dataset currently available has one cohort's data (Fall 2010) available through NSCRC. Their initial report in 2017 is the first to set a benchmark for graduation rates of transfer students (Shapiro, Dundar, Huie, Wakhungu, Yuan, & Hwang, 2017). However, it only looks at transfer students that completed a degree at a community college, continued to a bachelor's degree, and obtained the degree within six years of beginning at the community college. Given most associate degrees are earned in two years, this would be a four-year graduation rate. Several data points are missing from this report including first-to-second year retention at the receiving institution, three-year graduation rate, students that transfer after one year and do not earn an associate degree, and any student completing a lateral transfer. Therefore, we do not have historical data at the national level to develop a complete reference mode of transfer student persistence. Additionally, the existing research only shows data on all transfer students, it does not have any data on only engineering students.

Using a single-institutional longitudinal dataset, reference modes have been created to show comparisons between all transfer students at the institution, and only engineering transfer students. The reference modes represent first-to-second year retention rates and 4-year graduation rates since 2007. Figure 2.3 (VT OIR, 2017) shows the reference mode for first-to-second year retention rate, and demonstrates oscillations in both institutional and engineering transfer retention rates, with minimal improvement over the last decade. However, the engineering transfer student retention rates show more volatile oscillations.

Figure 2.3 Retention Rates for Institution and Engineering Transfer Students

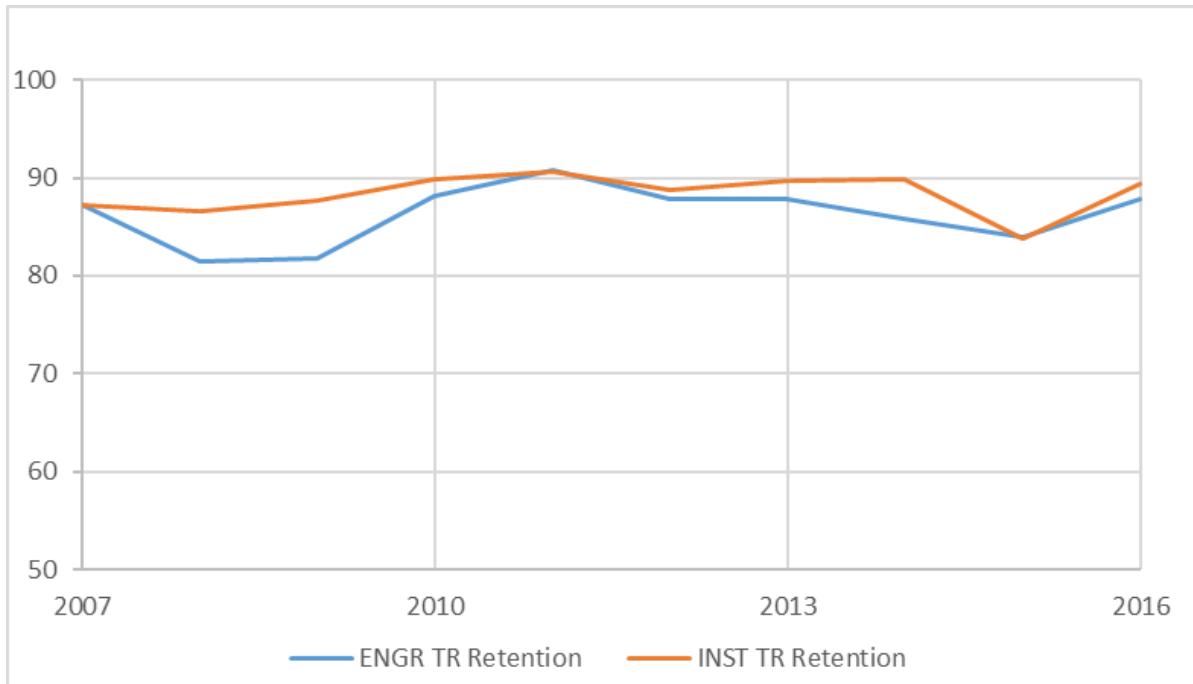
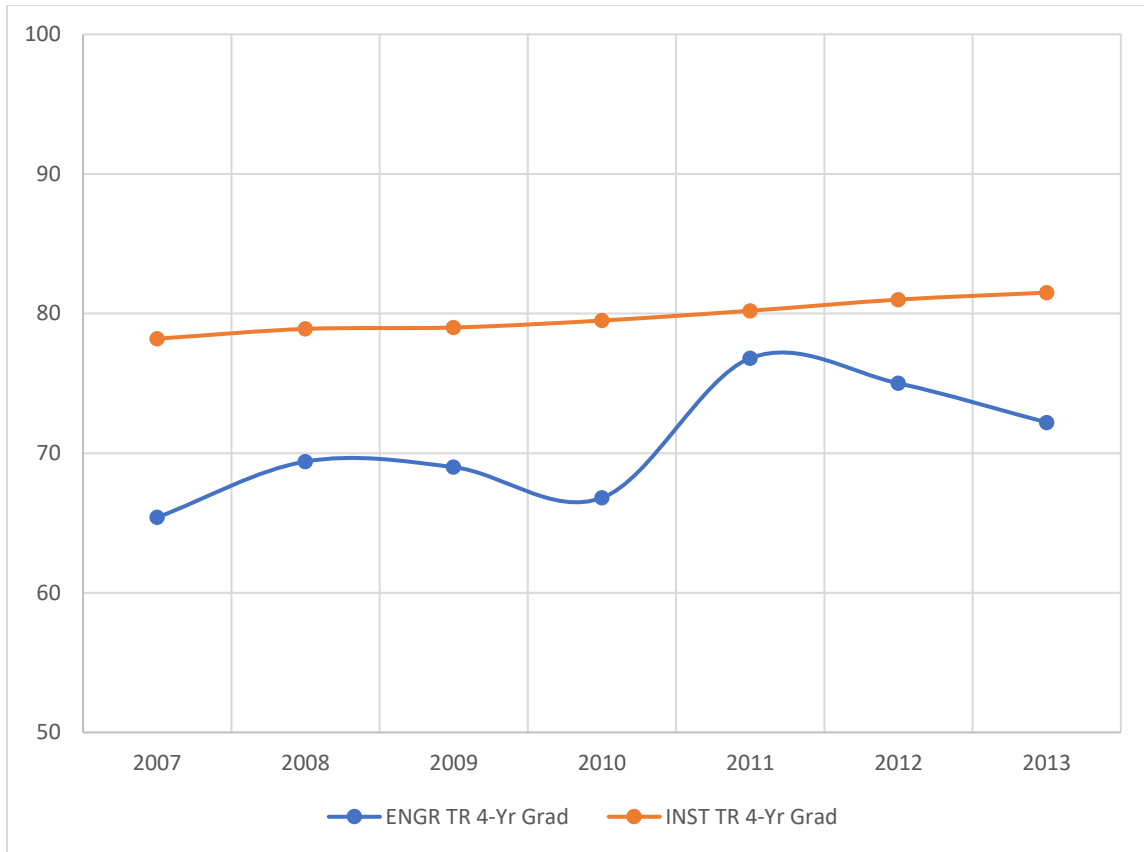


Figure 2.4 (VT OIR, 2017) provides a reference mode of the four-year graduation rates. We see graduation rates for transfer students at the institution are gradually increasing and the oscillations have ceased. However, the engineering transfer student graduation rates, while increasing, are still oscillating.

Figure 2.4 Graduation Rates for Institution and Engineering Transfer Students



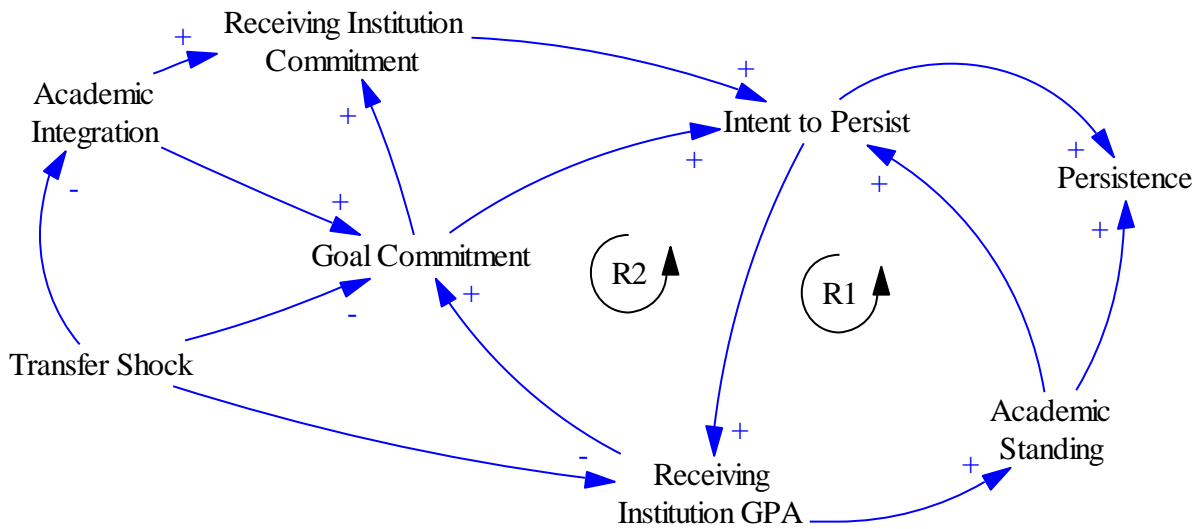
These oscillations indicate a negative feedback loop exists with significant time delays (Sterman, 2000). There could be several reasons for the oscillations including: the time it takes measure and report on student persistence, the time it takes to review the reported data and determine the necessary corrective action, the time it takes to develop the programming needed for the determined corrective action. Though it is a single-institution, the reference modes provided in Figures 2.3 and 2.4 provide an appealing case towards using system dynamics to uncover what is leading to the oscillations in engineering transfer student persistence.

## 2.8 Causal Loop Diagram

Cabrera, Nora, and Castaneda's (1993) student integrated model can be modified to include transfer shock as a variable and include causal links between several variables. Figure 2.5

represents these new additions as a causal loop diagram (CLD) which reinforces the integration of students as influential to their persistence, and highlights the direct relationship of transfer shock and academic integration. This CLD adds to Cabrera, Nora, and Castaneda’s model by illustrating that transfer shock has an impact on academic integration.

Figure 2.5 Preliminary Causal Loop Diagram of Transfer Student Retention



This preliminary CLD highlights two reinforcing loops. R1 demonstrates that as the receiving institution GPA increases, the students’ academic standing increases, which increases their intent to persist, and that in-turn increases the GPA. R2 represents another reinforcing feedback loop that highlights how an increase in GPA will lead to a higher commitment towards goals, which leads to an increase in intent to persist. Both feedback loops are based on Vroom’s (1964) expectancy theory which states individuals are motivated based on what they perceive an outcome will be. In this instance, as a student’s academic standing improves, their motivation to persist increases, which leads to more effort towards their studies and an increase in GPA, leading

to a virtuous cycle. However, a vicious cycle can easily be formed if any of those variables begin to decline.

The CLD is meant to highlight how system dynamics can be used in transfer student persistence modeling. Additional research must be conducted to further enhance the model and determine additional variables that should be added in an attempt to learn where the negative feedback loops and time delays are occurring, and develop the CLD into a stock and flow simulation model, which will be future work of the author.

## 2.9 Conclusions

Engineering transfer students are an becoming an increasing population and could play a pivotal role in increasing the number of STEM graduates in the U.S. Their widely-varying backgrounds pose challenges for higher education institutions as they look to determine how to attract, retain, and graduate these students. This paper highlights how system dynamics can be used to include success factors of this student population, including transfer shock, to understand the movements of the various engineering transfer student types through the system and demonstrate the effects of feedback loops on the behavior of the system. The development of a system dynamics model would provide an avenue to test policies and determine their consequences on the behavior of the system. The result would be a tool that fosters developing a more efficient and effective engineering transfer student persistence model that addresses transfer shock and increases engineering transfer student persistence.

Future work will include a completing a systematic literature review of engineering transfer student persistence to identify a comprehensive list of factors impacting engineering transfer student persistence, analyzing a longitudinal institutional dataset, and developing and testing a

system dynamics model. The resulting contributions will advance the fields of engineering education and enrollment management through a transformation in how each view transfer students and the types of programming put in place to increase student success, as well as provide new information about the inherent dynamics of the system.

Additionally, the research will advance the field of system dynamics as this has not been a method used to understand and improve student persistence, and highlights enrollment management as a field well positioned to benefit from additional engineering management practices that provide useful methods for understanding the complexity and non-linearity of student persistence and enable better decision-making.

## References

- Bean, J. (1980). Dropouts and turnover: The synthesis and test of a causal model of student attrition. *Research in Higher Education*. Vol. 12, No. 2, pp. 155-187.
- Bean, J. & Metzner, B. (1985). A conceptual model of non-traditional undergraduate student attrition. *Review of Educational Research*. Vol. 55, No. 4, pp. 485-540.
- Boeing, G. (2016). Visual analysis of nonlinear dynamical systems: chaos, fractals, self-similarity and the limits of prediction. *Systems*. Vol 4, No. 4, pp. 37-54.
- Braxton, J.& Lee, S. (2005). Toward reliable knowledge about college student departure. *In A. Seidman (Ed.) College Student Retention: Formula for student success*. Greenwood Publishing Group.
- Cabrera, A., Nora, A., & Castaneda, M. (1993). College persistence: structural equations modeling test of an integrated model of student retention. *The Journal of Higher Education*. Vol. 64, No. 2, pp. 123-139. doi:10.2307/2960026

- Carlan, P. & Byxbe, F. (2000). Community colleges under the microscope: an analysis of performance predictors for native and transfer students. *Community College Review*. Vol. 28, No. 2, pp. 77-93.
- Clinedinst, M. & Koranteng, A. (2017). *State of College Admission*. National Association for College Admission Counseling.
- D'Amico, M., Dika, S., Elling, T., Algozzine, B., & Ginn, D. (2014). Early integration and other outcomes for community college transfer students. *Research in Higher Education*. Vol. 55, No. 4, pp. 370-399.
- Georgetown University Center on Education and the Workforce. (2013). *Recovery: Job Growth and Education Requirements*. Retrieved from [https://cew.georgetown.edu/wp-content/uploads/2014/11/Recovery2020.FR\\_.Web\\_.pdf](https://cew.georgetown.edu/wp-content/uploads/2014/11/Recovery2020.FR_.Web_.pdf)
- Ghaffarzadegan, N., Larson, R., & Hawley, J. (2016). Education as a complex system. *Systems Research and Behavioral Science*. Vol. 34, No. 3, pp. 211-215.
- Glass, J. C., & Harrington, A. R. (2002). Academic performance of community college transfer students and “native” students at a large state university. *Community College Journal of Research and Practice*. Vol. 26, pp. 415-430. doi: 10.1080/0277677029141774.
- Graham, S. & Dallam, J. (1986). Academic probation as a measure of performance: contrasting transfer students to native students. *Community/Junior College Quarterly of Research and Practice*. Vol. 10, pp. 23-24.
- Hills, J. (1965) Transfer shock: The academic performance of the transfer student. *The Journal of Experimental Education*. Vol. 33, No. 3.
- Hogarth, R. (1987). *Judgement and Choice*, 2<sup>nd</sup> ed. Chichester, England: John Wiley and Sons.

- Holahan, C., Green, J., & Kelley, P. (1983). A 6-year longitudinal analysis of transfer student performance and retention. *Journal of College Student Personnel*. Vol. 24, No. 4.
- Ishitani, T. (2008). How do transfers survive after “transfer shock”? A longitudinal study of transfer student departure at a four-year institution. *Research in Higher Education*. Vol. 49, pp. 403-419.
- Ivins, Copenhaver, & Koclanes. (2017). Adult transitional theory and transfer shock in higher education: practices from literature. *Reference Services Review*. Vol. 45, No 2., pp. 244-257. doi.org/10.1108/RSR-08-2016-0048
- Jackson, D. & Laanan, F. (2015). Desiring to fit: fostering success of community college transfer students in STEM. *Community College Journal of Research and Practice*. Vol. 39, No. 5, pp. 132-149.
- Kanter, M., Ochoa, E., Nassif, R., & Chong, F. (2011). *Meeting President Obama's 2020 College Completion Goal*. Lecture presented at Department of Education. Retrieved from <https://www.ed.gov/news/speeches/meeting-president-obamas-2020-college-completion-goal>
- Lakin, J. & Cardenas Elliott, D. (2016). STEMing the shock: examining transfer shock and its impact on STEM major and enrollment persistence. *Journal of the First-Year Experience & Students in Transition*. Vol. 28, No. 2, pp 9-31.
- Li, Q, Swaminathan, H. & Tang, J. (2009). Development of a classification system for engineering student characteristics affecting college enrollment and retention. *Journal of Engineering Education*. Vol. 98, No. 4, pp. 361-376.

- Pascarella, E. T., Smart, J.C., and Ethington, C.A. (1986). Long-term persistence of two-year college students. *Proceedings from the 1986 Study of Higher Education Conference*. San Antonio, TX.
- President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Author.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Yuan, X., Nathan, A. & Hwang, Y. (2017). Tracking Transfer: Measures of Effectiveness in Helping Community College Students to Complete Bachelor's Degrees (Signature Report No. 13). *National Student Clearinghouse Research Center*.
- Snyder, T., de Brey, C., & Dillow, S. (2016). *Digest of Education Statistics 2015*. National Center for Education Statistics. U.S. Department of Education. Washington, DC.
- Sterman, J. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin/McGraw-Hall. Boston, MA.
- Sullivan, M., de Cohen, C., Orr, M., Long, R., & Ohland, M. (2012). Understanding engineering transfer students: Demographic characteristics and educational outcomes. 2012 Frontiers in Education Conference Proceedings. Seattle, WA. doi: 10.1109/FIE.2012.6462442
- Tobolowsky, B. & Cox, B. (2012). Rationalizing neglect: an institutional response to transfer students. *The Journal of Higher Education*. Vol. 83, No. 3, pp. 389-410.
- Virginia Tech Office of Institutional Research (VT OIR). (2017). Retrieved <http://ir.vt.edu/>
- Vroom, V. (1964). *Work and motivation*. Wiley. New York.
- Western Interstate Commission for Higher Education (WICHE). (2016). Knocking at the College Door: Projections of High School Graduates, Retrieved

<https://static1.squarespace.com/static/57f269e19de4bb8a69b470ae/t/58a73866bebafb9af53c8e4a/1487353994351/Knocking2016FINALFORWEB-revised021717.pdf>

## Chapter 3

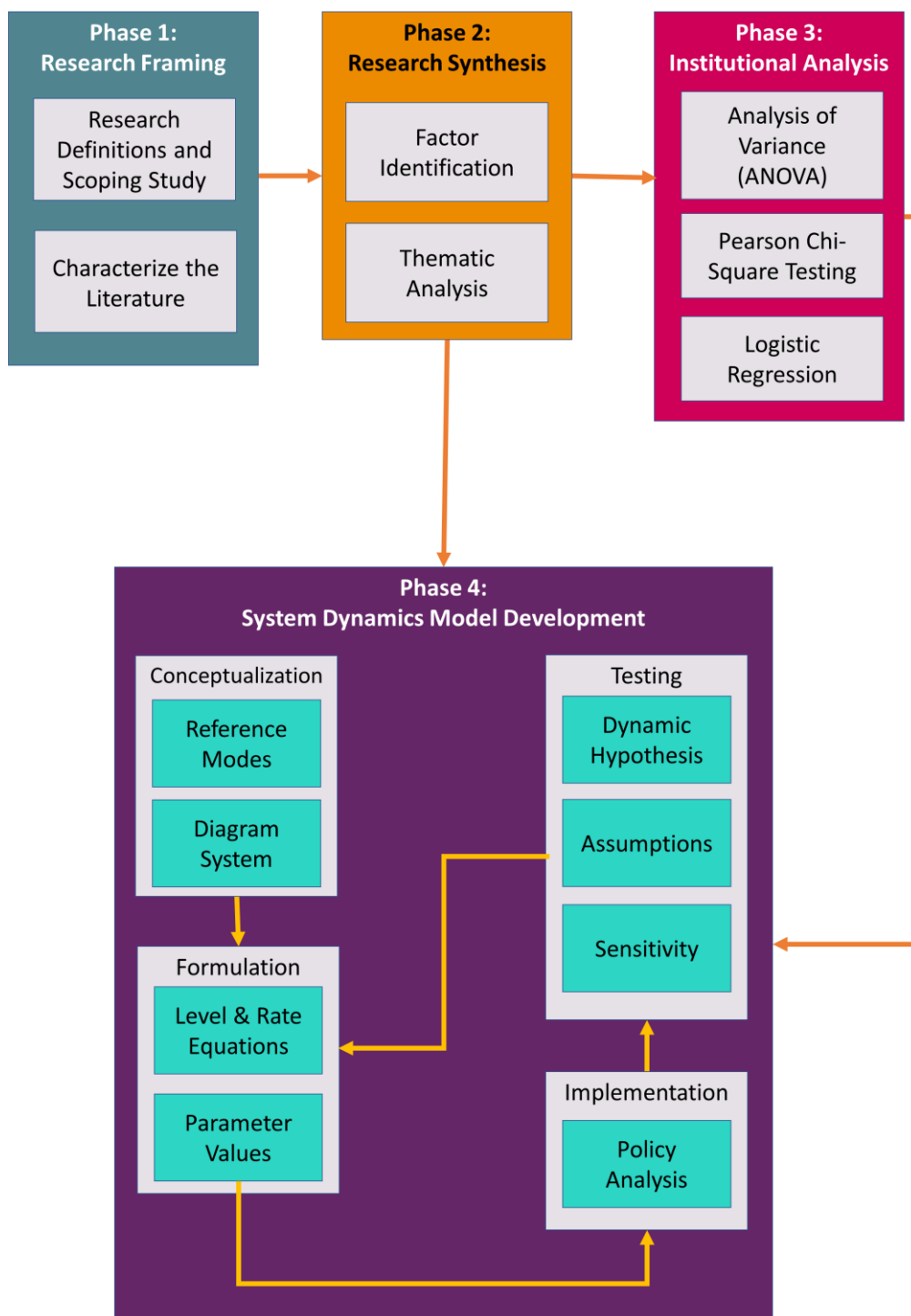
### Research Methodology Overview

An initial review of literature provided direction for the research objectives and appropriate methodologies were selected. To begin, the narrow focus in the literature and absence of a previous literature review suggested a need for a more comprehensive view of the existing literature. To further contribute to understanding this population of students, an institutional dataset was used for a quantitative analysis using a disaggregated approach to determine similarities and differences between the sub-groups of engineering transfer students. Lastly, persistence was modeled using non-linear tools to better understand the complexity of persistence and possible levers in the system. This chapter provides an overview of all methodologies used to complete the research objectives. Additional details for each can be found in Chapters 4, 5, and 6.

#### 3.1 Summary of Approach

The research methodology for this research is presented in four primary phases as shown in Figure 3.1. The first phase began with preliminary investigations as part of the research definitions and scoping study. Findings from this informed the search protocol for the systematic literature review that was used to characterize the literature. The next phase involved identification of all factors found in the final publication set and a thematic analysis to identify high-level themes within the factors. The third phase shifted the focus to an institutional dataset where several statistical methods were used to identify similarities and differences between the types of engineering transfer students. Finally, a system dynamics methodology was used to develop a more robust model of student persistence that highlights feedback loops and delays in the system, and their impact on engineering transfer student persistence.

Figure 3.1 Research Methodology



### 3.2 Research Framing and Synthesis

This phase began with an initial scoping study completed through a traditional literature review on engineering transfer student persistence. Twelve publications were identified in the scoping study. The findings from these publications indicated a shortage of research on this topic, and contradictory findings across the existing literature. The scoping study suggested a more comprehensive literature review was needed to include synthesis of the factors affecting engineering transfer student persistence, as well as to identify gaps within the literature and provide directions for future research.

The scoping study results were used to determine research definitions and to provide guidelines for development of a full-scale SLR. The methodology for this portion of the research is described in detail in Chapter 4. A six-step approach was adopted by Tranfield, Denyer, and Smart (2003) and included the scoping study described, search strategy protocol, applying exclusion criteria, data collection, analysis, and reporting. The SLR focused on identifying an exhaustive list of existing publications to identify a full range of factors identified as affecting engineering transfer student persistence. Four platforms with an extensive range of databases were searched to ensure that a wide sample of publication types and perspectives were captured, and over 2,000 publications were identified. Exclusion criteria were applied through three stages of review, including reviews of the title, the abstract, and the full publication. After all exclusion stages, 82 publications were selected, which were used to complete the research synthesis.

The research synthesis phase involved a thematic synthesis of the resulting publications from the SLR to identify the full range of factors discussed in the literature as affecting engineering transfer student persistence. A detailed description for this methodology can be found in Chapter 4. A three-step approach was used to code each of the publications, categorize the findings, and

determine themes across the findings. The thematic synthesis focused on the factors identified in the literature, as well as the persistence frameworks used to understand persistence of engineering transfer students. Findings from this process identified 34 factors, seven categories, and three themes across the factors. Additionally, 13 frameworks were identified as being used to understand persistence of this population.

### 3.4 Institutional Analysis

Phase three consisted of evaluating an institutional dataset to provide a better understanding of similarities and differences in transfer shock and graduation rates between sub-groups of engineering transfer students. A total of 789 engineering transfer students were included in this dataset. The students were admitted to a large public southeastern research institution between 2009 and 2014. A detailed description of the methodology can be found in Chapter 5.

The analysis began with compiling multiple institutional datasets. To identify sub-groups of engineering transfer students, a review of the sending institutions for each student was completed and appropriate coding was applied. Several variables were also computed from the available data and added to the dataset.

Once the data preparation was complete, a series of statistical analysis methods were implemented. First, descriptive statistics were used to determine the transfer shock measurements across the first three post-transfer terms of enrollment. The transfer shock measurements were calculated based on the difference between each student's transfer grade point average (GPA) and their post-transfer term GPAs at the end of the first, second, and third post-transfer terms. Second, a one-way ANOVA was used to determine if differences exist between the three transfer shock measurements across the sub-groups of engineering transfer students. Third, a chi-square test of

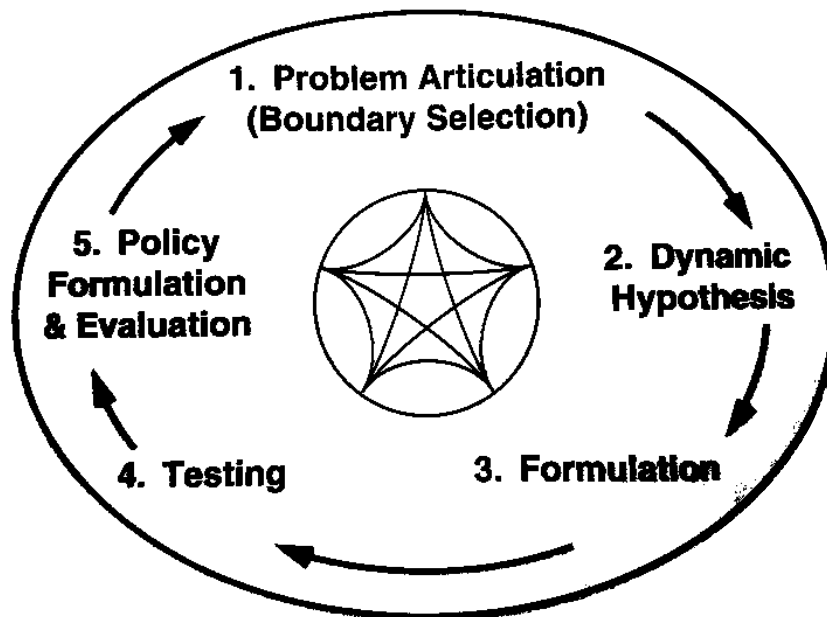
independence was used to determine differences in the percentages of students completing an engineering degree within four years for each of the sub-groups. Lastly, logistic regression was used to explore how transfer shock affected graduation within four years.

### 3.4 Model Development

Phase four involved the development and testing of a SD model that simulated the movement of engineering transfer students from their point of admission to when they exited the system. The students exit through leaving engineering, graduating in engineering, or continuing enrollment in engineering past four years. Chapter 6 provides a detailed description of the model development.

System dynamics model development is an iterative process that is broken into five stages: problem articulation (boundary selection), dynamic hypothesis, formulation, testing, policy formulation and evaluation (Sterman, 2000). Figure 3.2 represents the iterative nature of the process.

Figure 3.2 Stages of SD Modeling (Sterman, 2000)



The SD model was designed to determine key leaving patterns of engineering transfer students and how the institution can affect the leaving and graduation rates of this population. A classic aging-chain structure was used to move each entering cohort of students through their first four post-transfer years. The model boundary was supported by findings from the second and third phases of the research. Data from third phase was used throughout the model development to ensure the model was representative of the system. Multiple validation tests were also conducted throughout development, and the model was concluded to be a good fit.

## Chapter 4

### Systematic Literature Review and Thematic Synthesis

(Manuscript 2: Systematic Literature Review of Persistence of Engineering Transfer Students)

#### 4.1 Abstract

**Background** Increasing the number of engineering graduates continues to be a national priority, and influences the need to understand persistence of all student pathways. Few studies have focused on engineering transfer student pathways and their success post-transfer, suggesting a need for a more comprehensive analysis of existing research to advance this area.

**Purpose** A comprehensive literature review was conducted to identify the factors found in the literature that most significantly affect engineering transfer student persistence, discuss themes that span the factors, and identify the frameworks used in the literature to understand engineering transfer student persistence.

**Scope/Method** A systematic literature review method was used to capture a broad range of publications. A thematic synthesis approach was used to analyze the results of the final publication set.

**Results** The systematic review identified 82 publications in this research area, and analysis of these publications resulted in 34 unique factors and three overarching themes. Additionally, 13 persistence frameworks were identified as being used to understand engineering transfer student persistence.

**Conclusions** Findings from this work suggest that the primary methods institutions can use to increase persistence of this population are increasing pre-transfer academic requirements, increasing student integration, and providing an inclusive institutional culture. This review also supports the need for an updated persistence framework that considers the characteristics of engineering transfer students. Gaps within the literature were also identified and indicate a need to differentiate vertical and lateral transfer students, as well as extend the review of post-transfer academics beyond the first post-transfer year.

**Keywords** transfer student; persistence; systematic review

## 4.2 Introduction

In the mid-1970's, faced by a decline in high school graduates, higher education institutions in the United States (U.S.) made two significant adaptations - increasing marketing efforts to recruit prospective students and forming a more intentional approach to maintaining student enrollment (Hossler & Bontrager, 2015). With minimal change to the degree completion rates nearly half a century later, President Barack Obama issued a College Completion goal of increasing the degree attainment rate from 40% to 60% by the year 2020 (Kanter, Ochoa, Nassif, & Chong, 2011). Additionally, the President's Council of Advisors on Science and Technology found that the U.S. will need one million more science, technology, engineering, and math (STEM) professionals over the next decade to remain competitive (PCAST, 2012). The Bureau of Labor Statistics indicated engineering alone would have 500,000 job openings over the next 10 years (Fayer, Lacey, & Watson, 2017). However, the 2016 report from the Western Interstate Commission for Higher

Education found that fewer high school students will be graduating between 2014 and 2023 (WICHE, 2016).

There has been significant research on maintaining student enrollment, also described as persistence, in engineering. Persistence is formally defined by Pascarella, Smart, and Ethington (1986) as actively working toward a bachelor's degree within a nine-year period. Much of the engineering persistence literature focuses on the persistence of first-time, full-time (FTFT) students. However, more students are pursuing transfer pathways for completion of their bachelor's degree. The most recent National Student Clearinghouse (NCR) report shows that 21% of students who begin at a 4-year institution will transfer to another 4-year institution and that 22% of students who begin at a 2-year institution will transfer to a 4-year institution (Shapiro, Dundar, Huie, Wakhungu, Bhimdiwali, Nathan, & Youngsik, 2018). This is an increase from the 2012 report, which indicated 17% and 20%, respectively (Hossler, Shapiro, Dundar, Ziskin, Chen, Zerquera, & Torres, 2012).

A review of the existing literature on engineering transfer students uncovers variations in findings related to persistence. Some suggest that these students persist at lower rates than FTFT students (Ishitani, 2008; Ivins, Copenhaver, & Koclanes, 2017; Sullivan, de Cohen, Barna, Orr, Long, & Ohland, 2012). Other researchers find that they perform similarly or slightly better (Carlan & Byxbe, 2000; Glass & Harrington, 2002). Only one other literature review on engineering transfer students was found, which focused on the experiences of students transferring from a 2-year institution and identified gaps in the literature on pathways and outcomes for this population (Ogilvie, 2014). Understanding this population of students and how to improve their persistence within engineering can provide additional pathways to meet the nation's goals and need for engineering graduates.

A systematic review of the literature and thematic analysis was guided by two primary research questions. First, what factors have been identified in the literature that affect engineering transfer student persistence and are there themes across these factors? This question is important as institutions continue to receive more engineering transfer students. Having a comprehensive list of factors and possible themes will allow institutions to develop more robust policies and programming that can positively influence persistence of this population. Second, what theories or frameworks have researchers used to understand engineering transfer student persistence? This question is important for researchers as this increasing population can assist with meeting the demand of engineers. Understanding the framework and theories used in the existing literature will provide insight into how research on this population may differ from that of FTFT students. An in-depth review of the methods and detailed findings from the identified publications will be discussed as they relate to the research questions, as well as how the results are relevant to the engineering education community and suggestions for future research.

#### 4.3 Methods

A systematic literature review was selected in favor of a traditional literature review due to its ability to execute a more rigorous, methodological search and identify a more comprehensive listing of relevant publications across multiple fields (Higgins & Green, 2011; Tranfield, Denyer, & Smart, 2003). Borrego, Foster, and Froyd (2014) point to systematic literature reviews in engineering education as a method to enhance the foundation of the field, as well as provide future directions to accelerate its development.

The framework for this systematic literature review uses a six-step approach as presented by Tranfield, Denyer, and Smart (2003) and the Cochrane Collaboration (Higgins & Green, 2011; Tranfield et al., 2003). Additionally, the process is presented using the Preferred Reporting Items

for Systematic Reviews and Meta-Analyses (PRISMA) guidelines as outlined by Moher, Liberati, Tetzlaff, Altman, and the PRISMA group (2009).

#### 4.3.1 Search Strategy Protocol

A traditional literature review was conducted for the scoping study with an objective of gaining an initial overview of existing publications in the research area. Twelve publications were identified in the scoping study and served as the basis for the remainder of the study. The search strategy was created from the 12 publications, and was designed to broaden the findings through searching across multiple databases and including more search phrases. The search strategy protocol consists of platforms, search terms, and delimiters. Four platforms were selected to include a broad range of document types and literature areas. *EBSCOhost*, including the ERIC database, and *ProQuest* were chosen to capture publications in the social science and education domains. *Engineering Village* and *Web of Science* were chosen for their focus on engineering literature.

The search terms were based on the initial scoping study and iterative sample searches, and can be broken into four distinct search concepts. *Institution type* was selected to include undergraduate students in college and to exclude students in high school or graduate school. *Student admit type* includes transfer students and excludes publications focused on only FTFT students. *Student degree type* includes students in engineering and STEM and excludes works that do not specifically discuss engineering or STEM students. *Student persistence* includes the various terminologies used across the literature to discuss student persistence with no deliberate exclusions. Table 4.1 provides details on the specific terms used for each concept. Boolean operators were used in the search, including the AND operator across concepts and the OR operator

between terms within each concept. All 12 publications from the scoping study were found in the SLR.

Table 4.1 Search Concepts and Terms

<b>Concept 1:</b> <i>Institution Type</i>	<b>Concept 2:</b> <i>Student Admit Type</i>	<b>Concept 3:</b> <i>Student Degree Area</i>	<b>Concept 4:</b> <i>Student Persistence</i>
Undergraduate College University Higher education	Transfer student	Engineering STEM	Attrition Degree attainment Departure Drop-Out Persistence Retention Success Transition

The search was conducted across all platforms by searching for the terms within the title, abstract, and full-text. This method allowed for an inclusive search that contains publications with a focus on FTFT students, but also considered transfer students. When the full-text of a publication was not available through the platform on which it was initially identified, other means were used such as Google Scholar and the library database offered by the authors' university. The only limitation used was that the publication needed to be in English. Table 4.2 summarizes the search results from each platform with raw results and those once the English limiter was in place. The searches resulted in a total of 2,016 publications.

Table 4.2 Initial Search Results

<b>Platform</b>	<b>Raw Results</b>	<b>With Limiter (English Language)</b>
EBSCOhost	295	259
Engineering Village	673	668
ProQuest	932	909
Web of Science	206	180
<b>Total</b>	<b>2,106</b>	<b>2,016</b>

### 4.3.2 Selection Process

Rayyan QCRI, an open-source web application for systematic literature reviews, was used to manage the publications identified from this search. The application found 220 duplicates within the platforms and an additional 171 duplicates across the platforms, resulting in 1,635 unique publications to be reviewed. This result demonstrates the importance of performing searches across multiple platforms, as only 9% of the publications were duplicated across the platforms used in this work. Once the initial publication set was identified, multiple exclusion rounds, described below, were conducted using pre-determined exclusion criteria to identify the final publication set.

### 4.3.3 Applying Exclusion Criteria

The publications were screened in three phases, with the first phase based on the publication title, the second on the abstract, and the third on a full review of the publication. Each publication needed to focus on undergraduate transfer students in engineering or STEM and discuss student persistence. At each phase, the exclusion criteria (EC) below were used to determine the appropriateness of the publication to move forward to the next review.

**EC 1:** Focus is not on post-transfer persistence

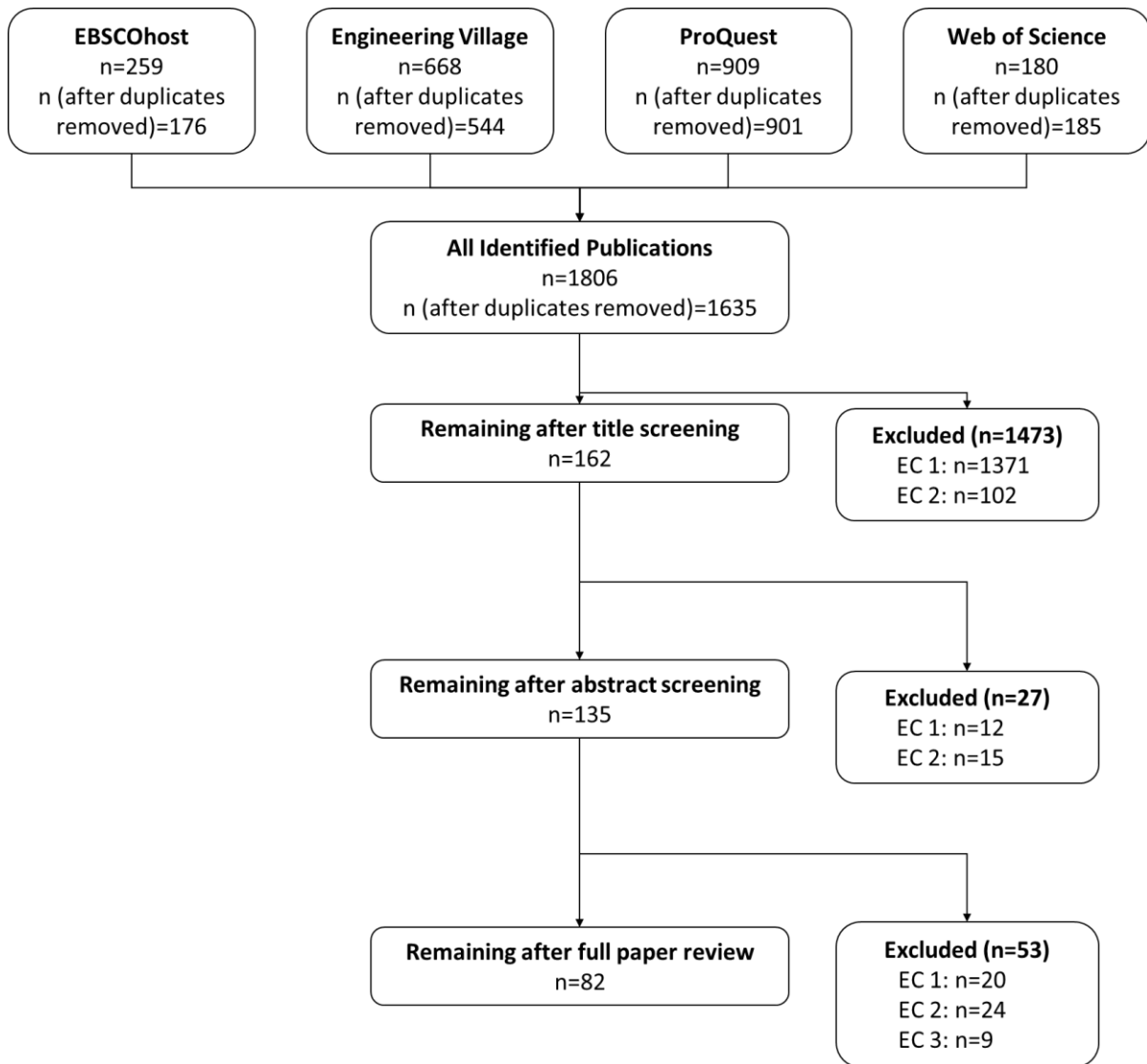
**EC 2:** Focus is not students that are specifically engineering or STEM transfer students

**EC 3:** Extension of previous publication with no new findings

The first review phase was based solely on the title of the 1,635 identified publications; 1,473 publications were excluded in this phase. For the remaining 162 publications, the abstracts were reviewed, and the same exclusion criteria were applied, resulting in an additional 27 publications being excluded. Finally, the full text was reviewed for the remaining 135 publications and the exclusion criteria were applied to eliminate 53, resulting in a final set of 82 publications. Figure

4.1 provides an overview of the selection and exclusion process. All 82 publications in the final publication set used for analysis are denoted in the references with an asterisk (\*).

Figure 4.1 Overview of review process based on PRISMA guidelines (Moher et al., 2009)



#### 4.3.4 Limitations

There are two main limitations to the methods used in this study. First, relevant publications not indexed in the platforms searched could have been omitted. This limitation was addressed by

searching across four different platforms to minimize this risk. Second, researcher bias exists in this review. To help mitigate this, peers were asked to validate the process of the systematic review and discuss the coding process used in applying the exclusion criteria.

Two delimiters were also used in the search strategy which impact the findings in this research. First, the study was limited to publications in the English language, which creates an opportunity to miss articles on the topic where English is not the primary language. Second, transfer students in a discipline outside of STEM were excluded from this review. However, these were intentional limitations due to the focus on engineering transfer students.

#### 4.3.5 Analysis

A thematic synthesis process was selected for the analysis of the final publication set from the SLR. This synthesis process is similar to meta-synthesis, which synthesizes quantitative findings. The thematic synthesis is more commonly used for synthesis of qualitative information. This method provides steps to review the information and uses an iterative process to describe findings across the literature. The process involves three stages: free-coding of the primary studies, developing categories, and development of the themes (Thomas & Harden, 2008). The free-coding was completed by reviewing each publication and placing findings related to each initial code into a matrix. An initial set of broad codes were used for the matrix, which were based on a review of the scoping studies. As publications were reviewed, new codes were added when necessary. Appendix A outlines the codes used. After free-coding all publications, the second phase was to categorize the findings from the free-coding. This was completed through an iterative synthesis of the matrix to identify similarities and differences. This step included creating new codes and categories to integrate all findings into a final set of categories (Britten, Campbell, Pope, Donovan,

Morgan, & Pill, 2002; Fisher, Qureshi, Hardyman, & Homewood, 2006). Lastly, a review of the free-coding and the categories helped to determine overarching themes that provide a more holistic understanding of the current literature on engineering transfer students (Britten et al., 2002; Thorne, Jensen, Kearney, Noblit, & Sandelowski, 2004). The findings are discussed in the next section.

#### 4.4 Findings

The findings related to each research question are described in this section. The first question focuses on understanding the factors affecting engineering transfer student persistence that were identified in the literature. This includes identification of the factors, how the factors can be categorized, and themes across the factors. A total of 34 factors were identified, which were placed into seven categories, and three themes were developed based on these findings. The second question focuses on what persistence frameworks have been used to understand engineering transfer student persistence. A total of 13 frameworks were cited in the literature that were used to understand engineering transfer student persistence. However, most frameworks have been developed based on FTFT students and do not consider many of the unique traits of engineering transfer students.

##### 4.4.1 Question 1: Factors identified as affecting engineering transfer student persistence

The first research question addresses identifying the factors determined to affect persistence in engineering transfer students. A total of 34 unique factors were identified and are presented in Appendix B. In the publications reviewed, some factors were discussed with positive or negative associations but have been coded in this work using neutral terms when possible. For example,

some researchers propose peer mentoring as a predictor of persistence, while others indicate a lack of peer mentoring having a negative effect on persistence. The factor is coded as peer mentoring. Once the factors were identified, we used an iterative review process to develop seven categories which represent logical groupings of the 34 factors. The categories are student characteristics, pre-transfer academics, post-transfer academics, goals and commitments, student integration, institutional culture, and academic advising. The categories and their corresponding factors are shown in Figure 4.2. The figure includes the frequency of each factor in the final publication set, expressed as a percentage of the 82 publications. The superscripts next to the category name also represent if the category and the factors within it are influenced by student attributes, institution attributes, or both.

Figure 4.2 Categories and Factors Identified from the Literature

<p><b>Student Characteristics <sup>1</sup></b></p>	<p><b>Pre-Transfer Academics<sup>1</sup></b></p>	<p><b>Institutional Culture <sup>2</sup></b></p>	<p><b>Academic Advising<sup>2</sup></b></p>
<p>Scholarship recipient (24%) Demographics (16%) (gender, race, ethnicity, age) Parental Education (6%) Financial need (2%) Residency (1%)</p>	<p>Number of credits completed (13%) Overall GPA (10%) Completion of associate degree (9%) Core engineering courses completed (7%) GPA in core engineering courses (5%) Sending institution accreditation (1%) High school class rank (1%)</p>	<p>Peer Mentoring (22%) Faculty Mentoring (11%) Supportive campus environment (7%) Right to fail policies (1%)</p>	<p>Specialized transfer academic advising (60%) Transfer specific orientation (11%) Information available on internet (1%) Review of mid-semester grades (1%)</p>
<p><b>Post-Transfer Academics<sup>3</sup></b></p>	<p><b>Student Integration <sup>3</sup></b></p>	<p><b>Goals and Commitments<sup>3</sup></b></p>	
<p>First fall credit hours (5%) First fall GPA (2%) First spring credit hours (1%) First spring GPA (1%) Withdrawing from an engineering course (1%)</p>	<p>Social integration (18%) Interaction with faculty (10%) Interaction with peers (6%) Undergraduate research (5%) Campus involvement (4%) Learning communities (2%)</p>	<p>Motivation (7%) Number of hours worked per week (2%) Degree goals (1%)</p>	

<sup>1</sup> Student-Influenced

<sup>2</sup> Institution-Influenced

<sup>3</sup> Student- and Institution-Influenced

#### 4.4.1.1 Student Characteristics

Student characteristics refer to a set of factors used to broadly define the students. The students' demographics includes gender, race, ethnicity, and age. Some studies uncover the demographics as independent factors impacting persistence of engineering transfer students (Lee & Schneider, 2016; Tkacik, Lim, Tolley, & Warren, 2012). Other researchers found an interaction of gender, race, ethnicity, and age as impacting engineering transfer student success (Cosentino, Sullivan, Gahlawat, Ohland, & Long, 2014; Ivins et al., 2017; Lakin & Cardenas Elliott, 2016; Shields & Pietroburgo, 2000). Increases in parental education level were linked to increased degree aspirations (Knight, Bergom, Burt, & Lattuca, 2014; Lee & Schneider, 2016). Financial need was found to have a negative impact on persistence of engineering transfer students (Cosentino et al., 2014; Hutton, 2015). The receipt of a scholarship was cited in 20 publications as being impactful to engineering transfer student persistence. The National Science Foundation (NSF) sponsors scholarships in science, technology, engineering and math (S-STEM), and they were the most referenced scholarships in the literature. The scholarship amounts range from \$250 to full tuition for two years at a 2-year institution and two years at a 4-year institution. Each study demonstrated that the scholarship money improved student persistence rates.

#### 4.4.1.2 Pre-Transfer Academics

Pre-transfer academics refer to the academic accomplishments of the students prior to their transfer. Multiple researchers found that the more credits a student earned prior to transferring, the better they performed at the receiving institution (Anderson-Rowland, Rodriguez, & Grierson, 2015; Lakin & Cardenas Elliott, 2016; Lopez & Jones, 2017; Shields & Pietroburgo, 2000). Other researchers found that students with an earned associate degree had higher persistence rates at their

receiving institution (Hutton & Panter, 2015; Ivins et al., 2017; Lee & Schneider, 2016; Lopez & Laanan, 2012; Mattis & Sislin, 2005). The courses completed at the sending institution also have a significant impact on the student's persistence at the receiving institution. Specifically, according to the literature reviewed in this work, students should complete as many core engineering-related courses as possible and should have Calculus I and II, as well as one semester of physics at a minimum (Darrow & Laanan, 2012; Laugerman, Rover, Shelly, & Mickelson, 2015; Laugerman & Shelly, 2013; Laugerman, Shelley, Rover, & Mickelson, 2015). Additionally, the student's overall GPA from their sending institution was shown to be a strong determinant of engineering transfer student persistence (Anderson-Rowland, 2011; Illinois Community College Board, 1986; Ivins et al., 2017; Lakin & Cardenas Elliott, 2016; Lopez & Jones, 2017; Lopez & Laanan, 2012; Shields & Pietroburgo, 2000). A student's GPA in core engineering courses was also found to be a significant predictor of engineering transfer student persistence (Shields & Pietroburgo, 2000).

#### 4.4.1.3 Post-Transfer Academics

Post-transfer academics refer to the academic accomplishments of the students after their transfer. Multiple authors show an increase in the number of credits taken in the first fall semester leads to higher persistence rates for these students (Anderson-Rowland, 2009; Laugerman & Shelley, 2013; Laier & Steadman, 2014; Lakin & Cardenas Elliott, 2016). Additionally, persistence increases as the GPA in the first semester increases (Laugerman & Shelley, 2013; Laugerman et al., 2015). The first semester GPA was also commonly associated with the term "transfer shock." This refers to a drop in GPA that transfer students commonly experience when transitioning to a new institution (Hills, 1965). The majority of engineering transfer students experience transfer shock (Anderson-

Rowland, 2011), and those transferring from a 2-year institution, especially those with an associate degree, were found to have a greater prevalence of transfer shock (Lakin & Cardenas Elliott, 2016).

#### 4.4.1.4 Goals and Commitments

Goals and commitments refer to the motivation and degree goals of the students, as well as work commitments they may have. Motivation was typically discussed through an intrinsic desire to problem solve or a perception of the prestige of engineering. Both types of motivation were seen to increase student persistence (Allen & Zhang, 2016; Alting, Delale, & Barba, 2013; Anderson, Perez, Jones, & Zafft, 2011; Darrow & Laanan, 2012; Mobley & Brawner, 2013; Zamudio & Davis, 2015). Additionally, Lee and Schneider (2016) posit that motivation is also driven by the student's degree aspirations. Those intending to pursue graduate school were shown to have a higher persistence rate than those only focused on a bachelor's degree. Many engineering transfer students also work part-time or full-time; researchers suggest that as the number of hours worked per week increases, persistence declines (Lee & Schneider, 2016; Shayevich, Goldberg, & Edson, 2008).

#### 4.4.1.5 Student Integration

Student integration encompasses the various ways students can integrate into the receiving institution. Active participation in each of these is shown to have a positive impact on engineering transfer student persistence, and is consistent with the broader literature on student persistence (Astin, 1999; Tinto, 1993). Additionally, Marra, Chia-Lin, Bogue, and Landa Pytel (2015) assert that social integration, as well as interactions with faculty and peers, are essential for engineering transfer student persistence. Programs with designs that mandated some of these factors saw

improvements in student persistence (Brawner & Mobley, 2016; Cotts, Fang, Jones, Klotzkin, Myers, & White, 2016; Laier & Steadman, 2014; Lopez & Jones, 2017; Scott, Thigpin, & Bentz, 2017).

#### 4.4.1.6 Institutional Culture

Student integration is important, but institutional culture is also a vital part of persistence of engineering transfer students (Townley, Katz, Wandersman, Skiles, Schillaci, Timmerman, & Mousseau, 2013). The campus environment plays an essential role in a student's sense of community which impacts their overall social integration (Darrow & Laanan, 2012). A supportive environment for engineering transfer students promotes and attracts increased campus engagement and increases students' social integration with faculty and peers. As part of a supportive campus environment, having peer and faculty mentoring programs specifically designed for engineering transfer students was shown to increase engineering transfer student persistence (Jackson, Starobin, & Laanan, 2013; Jefferson, Steadman, & Dougherty, 2013; Olson, Moll, Bullock, Miller, Jain, & Callahan, 2016; Sheinberg, 2105). "Right to fail policies" are policies that may unintentionally have a negative consequence on students, and include policies such as no attendance required or no minimum grades, as well as a general lack of advisement (Rendon, 1986). Rendon (1986) argues that eliminating "right to fail" policies is an element of a supportive campus environment.

#### 4.4.1.7 Academic Advising

Academic advising describes the guidance provided to students as they transition to the institution and in their continued journey through the higher education system (NACADA, 2017). Specialized

academic advising was described as a dedicated advisor or team of advisors by some researchers (Jones & Waggenspack, 2015; Laier & Steadman, 2014; Massi, Lancey, Nair, Straney, Georgiopoulos, & Young, 2012; Sarder, 2013). Others went a step further to recommend a transfer center that includes academic advising, among other resources, specifically dedicated to these students (Anderson-Rowland, 2011; Rendon, 1986). One common thread among all researchers discussing academic advising is the necessity of a transfer-focused orientation.

As part of the specialized transfer advising, the review of mid-term grades for transfer students and intrusive advising practices for those not meeting the standards was found to positively influence persistence of this population (Sarder, 2013; Scott et al., 2017; Skurla & Eisenbarth). Additionally, the accessibility and usability of advising websites were found to impact engineering transfer student persistence (Brawner & Mobley, 2016).

The categories for the factors found from this review were then identified as student-influenced, which were based on a student attribute or performance, or institution-influenced, which were based on services or programs offered at the receiving institution. Additionally, some categories were classified as both student-influenced and institution-influenced. The receipt of a scholarship was the most often-cited student-influenced factor. Consistent with literature on first-year engineering students (Astin, 1999; Tinto, 1993), demographics (gender, race, ethnicity, and age) was an often-identified factor influencing persistence as well. The number of credits completed at the sending institution is commonly cited as a factor, in addition to a student's overall GPA and completion of an associate degree, which highlights the importance of a student's academic preparation to their persistence.

Specialized transfer advising is the most cited institution-influenced factor, occurring in 60% of the publications. Paired with a specific transfer orientation, these two factors point to the responsibility of institutions to provide customized services to this population to increase their persistence. Peer and faculty mentoring were also cited frequently in the literature. All of these services are part of creating a supportive campus environment for engineering transfer students.

The factors influenced by both the student and institution demonstrate the need for students to choose to engage in the services and programming provided by the institution. The level of student motivation was also discussed in the literature as something a student arrives with but that can be influenced by practices within the receiving institution. The transfer credits students earned by the students also influences their first fall credit hours, in addition to recommendations through academic advising.

The literature highlights the impact of both student-influenced and institution-influenced factors. This is in line with many of the student persistence models that indicate that the institutional environment is important to the success of FTFT students (Astin, 1999; Tinto, 1993). For example, it is not enough for the institution to have mentoring programs on campus; an effort must be made to create mentoring specifically for engineering transfer students as their needs and engagement levels differ from those of FTFT engineering students (Allen & Zhang, 2016; Anderson, 2011). These findings suggest that focusing on only student-influenced factors or institution-influenced factors is not the best approach. Rather, researchers and practitioners should develop strategies that incorporate both types of factors to increase their impact.

Categorizing the factors provided a method for understanding similarities and differences between the factors. It also allowed us to determine themes that spanned across multiple factors and categories. Three themes were identified based on our analysis. The first relates to the need

for engineering transfer students to integrate into their institution and the obstacles caused by their financial need to work while pursuing a degree. This limitation is especially true in engineering where support mechanisms have increased importance, but the workload associated with the courses exacerbates the issue (Bahr, Toth, Thirolf, & Massé, 2013). The second theme relates to the students’ aspirational goals and motivation for engineering. Both are often driven by the students’ characteristics, which has a positive impact on their success. Academic advising and institutional culture can also influence a student’s aspirations both positively and negatively, which in turn affects their persistence. The third theme relates to students’ post-transfer performance, which is heavily influenced by their pre-transfer academics. Those with more credits, specifically engineering credits, and higher GPA’s were found to have higher persistence.

#### 4.4.2 Question 2: Frameworks used to understand engineering transfer student persistence

To address the second research question in this work, the persistence frameworks discussed in the publications were reviewed. A total of 13 unique frameworks were identified, as shown in Table 4.3.

Table 4.3 Identified Frameworks

<b>Framework</b>	<b>Field</b>	<b>Publications Using this Framework</b>
Astin’s Theory of Involvement	Higher Education	<ol style="list-style-type: none"> <li>1. Bohanna &amp; Ebberts, 2016</li> <li>2. Jackson &amp; Laanan, 2014</li> <li>3. Lee &amp; Schneider, 2016</li> <li>4. Lopez &amp; Laanan, 2012</li> <li>5. Lopez &amp; Jones, 2017</li> <li>6. Massi et al., 2012</li> <li>7. Mendez &amp; Fraser-Abder, 2001</li> </ol>
Tinto’s Theory of Integration	Higher Education	<ol style="list-style-type: none"> <li>1. Evans &amp; Mody-Pan (2010)</li> <li>2. Marra et al., 2015</li> <li>3. Hutton &amp; Panter, 2015</li> <li>4. Massi et al., 2012</li> </ol>

Transfer Student Capital	Higher Education	1. Darrow & Laanan, 2012 2. Jackson & Laanan, 2014 3. Mobley & Brawner, 2013 4. Ogilvie, 2014
Bean and Eaton’s Psychological Model of Student Retention	Psychology	1. Hutton & Panter, 2015 2. Lakin & Cardenas Elliott, 2016
Schlossberg’s Transition Theory	Psychology	1. Hagler & Sheridan, 2015 2. Lakin & Cardenas Elliott, 2016
Bandura’s Self-Efficacy Theory	Psychology	1. Concannon & Barrow, 2009
Bean and Metzner’s Student Attrition Model	Higher Education	1. Lee & Schneider, 2016
Bronfenbrenner’s Bioecological Systems Theory	Psychology	1. Bohanna & Ebbbers, 2016
Chickering and Gamson’s Theory of Student Involvement and Persistence	Higher Education	1. Lee & Schneider, 2016
Clark’s “Cooling Out”	Higher Education	1. Coyote, 2013
Knowles, Holton, & Swanson’s Theory for Adult Learning (Andragogy)	Higher Education	1. Allen & Zhang, 2016
Rendon’s Validation Theory	Higher Education	1. Bohanna & Ebbbers, 2016
Rhoades Concept of Managerial Professionals		1. Coyote, 2013

Astin’s Theory of Involvement is the most highly-cited framework in the publications reviewed in this work, appearing in nearly half of the publications that identified a guiding framework. Often referred to as the input-environment-output (I-E-O) model, the basis of this theory is that student outcomes are a function of inputs (such as student demographics) and the environment (such as their experiences at the institution) (Astin, 1999).

Tinto's Theory of Integration and Transfer Student Capital are the next two most-cited frameworks, each appearing in three of the publications. Tinto's theory uses the interactions of students with the academic and social aspects of their institution (Tinto, 1993). Transfer student capital, coined by Laanan (2004), is described as the accumulation of knowledge a student gains as they interact with their institution in social and academic settings.

Bean and Eaton's Psychological Model of Student Retention and Schlossberg's Transition Theory also each appear in two of the publications. Bean and Eaton's theory posits that students need certain attributes to become socially and academically integrated, and that those attributes can be developed (Bean & Eaton, 2001). Schlossberg's is a more widely-applied theory that focuses on transitions that one goes through. This theory states that while transition events may differ, the transition process is similar with adaptations and adjustments being based on one's self, the support available, and effective coping strategies (Schlossberg, 1984).

The remaining frameworks are only found in one publication and include a focus on how social and academic behaviors are linked to systems, gender, and the environment (Bronfenbrenner, 2005), adult learning (Knowles, Holton, & Swanson, 2005), the use of validation agents in and out of the classroom (Renden, 1994), and administrators or staff who are not professors but have a significant impact on an institution and experiences of their students (Rhoades, 1998).

Several factors that were identified as affecting engineering transfer student persistence in the first research question are not present in the commonly-used persistence frameworks outlined in Table 3. This finding demonstrates the limitations to current persistence frameworks when being applied to engineering transfer students. Many researchers identified the impact of *receiving scholarships* for this population. Any dollar amount was shown to have a positive impact on

transfer students, and many institutions are providing S-STEM grants through NSF. The receipt of a scholarship was largely connected with influencing the *number of hours worked per week*; the larger the scholarship, the fewer the number of hours a student has to work per week. These are important factors for the engineering transfer student population as many of them are working 20 or more hours per week, which is shown to negatively affect a student's academic performance (Anderson et al., 2011).

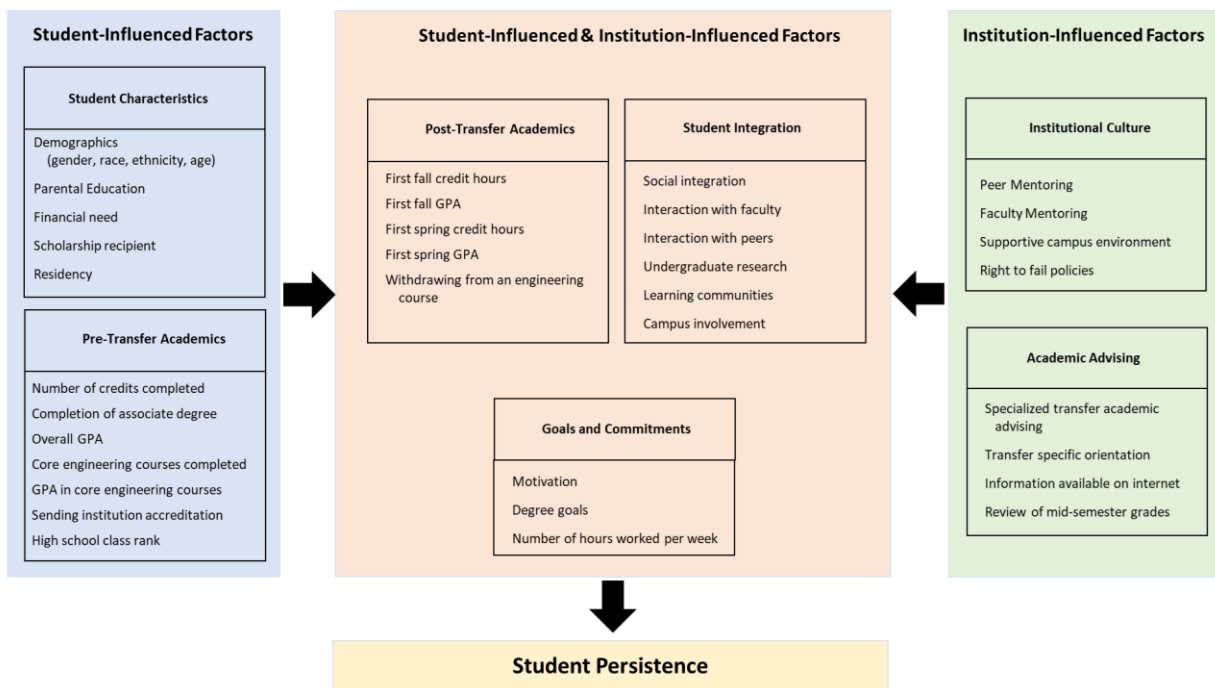
The total number of transfer credits is a factor in Laanan's (2004) Transfer Student Capital framework, however, Laanan's framework does not call out completion of specific courses at the sending institution. This literature review did find that the total number of transfer credits is a factor affecting persistence, but it also uncovered *completion of specific courses* (Calculus I and II and one semester of physics) as a factor influencing student persistence (Darrow & Laanan, 2012; Laugerman et al., 2015; Laugerman & Shelly, 2013; Laugerman, Shelley, Rover, & Mickelson, 2015).

Academic advising is highly cited in all persistence models, but multiple researchers found in this literature review discussed the importance of *specialized transfer advising* as being impactful to this population's persistence (Anderson-Rowland, 2011; Bohanna & Ebberts, 2016; Coyote, 2013; Jones & Waggenspack, 2015; Laier & Steadman, 2014; Massi et al., 2012; Mendez & Fraser-Abder, 2001; Rendon, 1986; Sarder, 2013). Specialized transfer advising for engineering transfer students can take many forms, including transfer-focused advisors, a transfer center, and transfer orientation.

To address the limitations of the current persistence frameworks, Figure 4.3 provides a conceptual model for engineering transfer student persistence. This conceptual model builds upon Tinto's Theory of Integration which outlines five main categories: pre-entry characteristics, goals

and commitments, institutional experiences, integration, and outcomes (Tinto, 1993). Our model is organized by student-influenced factors, institutional-influenced factors, and factors that are influenced by both. The pre-entry attributes in this conceptual model are described in the student-influenced factors and include engineering transfer specific factors such as core engineering courses completed, GPA in those core engineering courses, as well as other factors that also more broadly apply to all types of transfer students. Goals and commitments include intentions and external commitments. A key external commitment is the number of hours worked per week which is shown to be greater for engineering students (Anderson et al., 2011; Anderson-Rowland, 2013). The goals and commitments of the institution are reflected in the institutional culture and academic advising, and includes transfer specific academic advising and orientation sessions. Institutional experiences and integration are found in the post-transfer academics as well as student integration.

Figure 4.3 Literature-based Conceptual Framework of Engineering Transfer Student Persistence



#### 4.5 Discussion

A growing number of undergraduate students are transferring between institutions, and there is a limited amount of research on their persistence post-transfer. Increasing the number of engineering graduates continues to be a national priority in the U.S., and transfer students can provide an additional pathway to achieve this goal. Identification of factors affecting engineering transfer student persistence post-transfer will facilitate development of more inclusive policies and programming that are tailored to the needs of this student population. Demonstrating the overarching themes of engineering transfer student persistence will provide researchers with a direction for future research to better understand the experiences of these students and how they can be improved. The results of this work suggest that receiving institutions should go beyond simply creating the pathway for transfer students and learn more about the post-transfer experiences at their institutions and what they can do to improve persistence for this population.

In this study, we completed a systematic literature review focused on engineering transfer student persistence. Through this review we identified factors affecting their persistence and categorized the factors based on logical groupings. We also identified three themes that span across multiple categories and factors. The first theme relates to pre-transfer preparation. The post-transfer persistence of engineering transfer students is heavily influenced by the amount of engineering curriculum students complete prior to their transfer. Completion of core engineering courses pre-transfer is important, as is the rigor of those courses, which helps to academically prepare students for the rigor of courses they will take post-transfer (Darrow, 2012; Laugerman & Shelly, 2013; Laugerman, Rover, Shelly, & Mickelson, 2015). In addition to completing more core engineering courses, the GPA in those courses is also highly significant to persistence post-transfer (Shields & Pietroburgo, 2000). To improve student pre-transfer preparation, institutions can

provide pre-transfer course recommendations for engineering transfer applicants to encourage completion of a high number of pre-transfer engineering courses prior to transferring and recommend baseline GPA's within those courses.

The second theme relates to increasing social integration. Student integration has been found to be an important predictor of success in all students. However, engineering transfer students are found to be more academically involved, as a result of their engineering courses, which have significant out of class expectations, and limits their social integration (Lee & Schneider, 2016). Additionally, working continues to be a necessity for this population, with many working 20 or more hours per week (Anderson, et al., 2011; Anderson-Rowland, 2013). Parental education, financial need, and hours worked per week are consistent with proxy variables for socioeconomic status (SES) (Estep, 2016). According to the National Center for Education Statistics (Institute for Education Services, 2013), students with a lower socioeconomic status graduate at lower rates. This is consistent with Lee and Schneider's (2016) research which found that for every 1-hour decrease in hours worked per week, the odds of graduating increased by two times. The academic expectations, paired with the financial need to work while pursuing a degree, leaves little time for social integration and influences engineering transfer student persistence. To improve student integration, institutions can offer scholarships to help reduce the number of hours students need to work and encourage social integration activities as part of the scholarship requirements.

The third theme relates to creating an inclusive institutional culture. The motivation of engineering transfer students was also found to be an important predictor of persistence. Motivation for this population is often driven by student characteristics. However, academic advising and institutional culture can also influence a student's aspirations, both positively and

negatively. Mobley and Brawner (2013) posit that the combination of intrinsic motivation and institutional programs provide the best transition experiences for this population. Estep (2016) also calls for institutions to be more intentional in removing stereotypes of students of lower SES, which can positively influence students' aspirations.

This research also uncovered limitations to the current persistence frameworks that are often used to better understand engineering transfer student persistence. Lundberg (2014) asserted that successful student transition practices do not reflect the majority of transfer students. Manyanga, Sithole, and Hanson (2017) recommended updating and expanding academic success and retention models to reflect today's students, including transfer students. The conceptual framework provided in this review is an adaption of Tinto's Theory of Integration and follows the direction of Lee and Schneider (2016) to modify the five categories within Tinto's model to be more inclusive of the characteristics and experiences of engineering transfer students. The framework also defines the categories as student-influenced, institution-influenced, and those influenced by both.

Several directions for future research were identified through this review as well. First, a common finding throughout the literature was a focus on vertical transfer students, which aligns with findings from Tobolowsky and Cox (2012). Typically, the literature focuses on these types of transfers within the same state where transfer agreements often exist between the two types of institutions. However, the National Student Clearinghouse found that this type of transfer is no longer the predominant transfer pathway (Shapiro et al., 2015). Further research can examine differences between vertical and lateral transfer students. The only mention of differences between these two populations indicated that vertical transfer engineering students were more engaged than lateral transfer students (Lee & Schneider, 2016).

Second, several pre-transfer academic factors were discussed in the literature, but were limited to traditional first-year engineering courses (Calculus I and II, as well as one semester of physics). Further research can examine whether there are specific courses beyond the traditional first-year engineering courses that are better predictors of persistence if completed pre-transfer. Findings can inform admissions decisions at institutions to ensure engineering transfer students have these courses completed at a minimum, or at least strongly recommend them.

Third, after the first post-transfer year, no further academic performance-based factors were found in this literature review. Expanding the knowledge of academics past the first post-transfer year at the receiving institution may provide insight into additional ways to increase persistence of this population. Literature supports this continuous review of FTFT students (Wilder, 1993; McBurnie, Campbell, & West, 2012) and should also be considered with transfer students.

Lastly, the frameworks used to understand student persistence have limitations due to their focus on students attending a 4-year institution as FTFT students (Lee & Schneider, 2016). Engineering transfer students transition differently from FTFT students, and the existing frameworks do not capture these differences. Further research is needed to develop and validate a framework that can be used for transfer students.

#### 4.6 Conclusions

Engineering transfer students refer to the collective set of students that begin at one institution and transfer to a 4-year institution within the engineering discipline. These students may have started at a 2-year institution or another 4-year institution, and they represent a growing population of students enrolled in post-secondary institutions (Shapiro et al., 2018). This review examined the existing factors identified as affecting engineering transfer student persistence. Through this

review, themes were identified which suggest increasing pre-transfer preparation, increasing social integration, and creating an inclusive institutional culture, as key steps that institutions can take to improve persistence of this population.

The findings also identified important gaps in the literature, which should be the focus of researchers in future work. A majority of the final publication set was focused on students who completed a vertical transfer. Future studies should identify whether there are differences between lateral and vertical transfer students. Additionally, academic performance post-transfer only includes the first post-transfer year. Expanding past the first post-transfer year may provide additional insight into this population's success. Creating and validating a persistence framework that considers the unique characteristics of engineering transfer students is also an important consideration for future research.

Overall our findings are important for developing more strategically-designed services and programming, and provides future research directions for researchers as institutions seek to better serve engineering transfer students.

## References

- \*Allen, T. & Zhang, Y. (2016). Dedicated to their degrees: adult transfer students in engineering baccalaureate programs. *Community College Review*. Vol. 44, No. 1, pp. 70-86.
- \*Almatrafi, O., Johri, A., Rangwala, H., & Lester, J. (2017). Retention and persistence among stem students: a comparison of direct admit and transfer students across engineering and science. *2017 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Columbus, OH.

- \*Alting, A., Delale, F., & Barba, J. (2013). Bridges to engineering: success for transfers. *2013 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Atlanta, GA.
- \*Anderson, M., Perez, L., Jones, D., Zafft, C. (2011). Success factors for students transferring into undergraduate engineering degree programs. *2011 Frontiers in Education Conference (FIE) Proceedings*. Rapid City, SD.
- \*Anderson-Rowland, M. (2009). An academic scholarship program for transfer students in engineering and computer science: a five-year summary. *2009 American Society for Engineering Education (ASEE) Conference Proceedings*. Austin, TX.
- \*Anderson-Rowland, M. (2011). Reducing GPA shock for engineering and computer science community college transfer students. *2011 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Vancouver, B.C., Canada.
- \*Anderson-Rowland, M. (2013). Expectations and realities for community college engineering transfers at a large university. *2013 IEEE Frontiers in Education (FIE) Conference*. Oklahoma City, OK.
- \*Anderson-Rowland, M. (2013). Transfer experience for upper division engineering and computer science students. *2013 American Society for Engineering Education (ASEE) Annual Conference*. Atlanta, GA.
- \*Anderson-Rowland, M. & Grierson, A. (2010). Evaluating a university/community college collaboration for encouragement of engineering and computer science transfer students. *2010 American Society for Engineering Education (ASEE) Proceedings*. Louisville, KY.

- \*Anderson-Rowland, M. & Rodriguez, A. (2015). Sophomore transfers: who are they and what support do they need? *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- \*Anderson-Rowland, M., Rodriguez, A., & Grierson, A. (2015). Motivated engineering transfer students/step after six years. *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- \*Anderson-Rowland, M., Rodriguez, A., Hall, R., McBride, P., Pangasa, R., Saber, J., Vangilder, C., & Grierson, A. (2012). Leveraging S-STEM scholarship programs. *2012 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. San Antonio, TX.
- Astin, A. (1999). Student involvement: A developmental theory for higher education. *Journal of College Student Development*. Vol. 40, No. 5, pp. 518-29.
- \*Auerbach, J. & Williams, D. (2013). The ties program: a transfer initiative for engineering students. *2013 IEEE Frontiers in Education (FIE) Conference*. Oklahoma City, OK.
- Bahr, P., Toth, C., Thirolf, K., & Massé, J. (2013). A review and critique of the literature on community college students' transition processes and outcomes in four-year institutions. In: Paulsen, M (eds). *Higher Education: Handbook of Theory and Research*. Vol. 28, pp. 459-511. Springer, Dordrecht.
- \*Barnes, W. (1991). A comparison of BSET transfer students from ABET--accredited and non-accredited community colleges. 1991 Frontiers in Education (FIE) Conference Proceedings. West Lafayette, IN.
- \*Bayles, T. (2016). A chemical engineering success course for transfer students. *2016 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. New Orleans, LA.

- Bean, J. & Eaton, S. (2001). The psychology underlying successful retention practices. *J. College Student Retention*. Vol 3, No. 1, pp. 73-89.
- \*Bohanna, D. & Ebbers, L. (2016). Academic and social experiences of female community college transfer students in engineering fields at midwestern university. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- \*Bonsangue, M., Cadwalladerolsker, T., Fernandez-Weston, C., Filowitz, M., Hershey, J., Moon, H., Renne, C., Sullivan, E., Walker, S., Woods, R., & Engelke, N. (2013). The effect of supplemental instruction on transfer student success in first semester calculus. *Learning Assistance Review*. Vol. 18, No. 1, pp. 61-74.
- Borrego, M., Foster, M., & Froyd, J. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*. Vol. 103, No. 1, pp. 45-76.
- \*Brawner, C. & Mobley, C. (2016). Advising matters: engineering transfer students transition experiences at five institutions. *International Journal of Engineering Education*. Vol. 32, No. 6, pp. 2446-2459.
- Britten, N., Campbell, R. Pope, C., Donovan, J., Morgan, M., & Pill, R. (2002). Using meta-ethnography to synthesise qualitative research: a worked example. *Journal of Health Services Research & Policy*. Vol. 7, No. 4, pp. 209-215.
- Bronfenbrenner, U. (2005). Ecological systems theory. In U. Bronfenbrenner (Ed.). *Making human beings human: Bioecological perspectives on human development* (pp. 106-173). Thousand Oaks, CA: Sage.
- \*Brown, A. (1993). *Transfer retention at city college in engineering (TRACC) final report, September 30, 1992 – September 29, 1993*. Washington, DC. U.S. Department of Education.

- Carlan, P. & Byxbe, F. (2000). Community colleges under the microscope: an analysis of performance predictors for native and transfer students. *Community College Review*. Vol. 28, No. 2, pp. 77-93.
- \*Concannon, J. & Barrow, L. (2009). A cross-sectional study of engineering students' self-efficacy by gender, ethnicity, year, and transfer status. *Journal of Science Education and Technology*. Vol. 18, No. 2, pp. 163-172.
- \*Cosentino, C., Sullivan, M., Gahlawat, N., Ohland, M., & Long, R. (2014). Black engineering transfer students what explains their success? *2014 IEEE Frontiers in Education (FIE) Conference Proceedings*. Madrid, Spain.
- \*Cotts, E., Fang, J., Jones, W., Klotzkin, D., Myers, G., & White, B. (2016). A STEM program focused on transfer student success at Binghamton University. *2016 IEEE Frontiers in Education (FIE) Conference Proceedings*. Eerie, PN.
- \*Coyote, R. (2013). The relevance of career aspirations for transfer students persisting in science, technology, engineering and math disciplines. (Doctoral Dissertation). University of Arizona.
- \*Darrow, M. & Laanan, F. (2012). Engineering transfer student leavers: voices from the sidelines of the engineering playing field. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- \*Dowd, A., Pak, J., & Bensimon, E. (2013). The role of institutional agents in promoting transfer access. *Education Policy Analysis Archives*. Vol. 21, No. 15.
- Estep, T. (2016). The graduation gap and socioeconomic status: Using stereotype threat to explain graduation rates. *The SES Indicator*. Vol. 9, No. 3. American Psychological Association.

- \*Evans, H. & Mody-Pan, P. (2010). Using an adaptive Tinto framework to interpret successes of two-year institutions in retaining engineering students. *2010 American Society for Engineering Education (ASEE) Conference Proceedings*. Louisville, KY.
- Fayer, S., Lacey, A., & Watson, A. (2017). STEM occupations: past, present, and future. Spotlight on Statistics. *U.S. Bureau of Labor Statistics Spotlight on Statistics*. Retrieved February 2019 from <https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf>
- Fisher, M., Qureshi, H., Hardyman, W., Homewood, J. (2006). *Using Qualitative Research in Systematic Reviews: Older People's Views of Hospital Discharge*. London: Social Care Institute for Excellence, London, UK.
- \*Ford, D., Rees, P., & Rubin, K. (2015). The impact of federally funded scholarship programs on the success of transfer students at a public engineering college. *2015 American Society for Engineering Education (ASEE) Conference Proceedings*. Seattle, WA.
- Glass, J. & Harrington, A. (2002). Academic performance of community college transfer students and “native” students at a large state university. *Community College Journal of Research and Practice*, 26, 415-430. doi: 10.1080/0277677029141774.
- \*Gonzalez, F. & Pinzon, G. (2014). A stem transfer and retention program at Texas A&M international university. *2014 American Society for Engineering Education (ASEE) Conference Proceedings*. Indianapolis, IN.
- \*Gupta, S., Moon, J., Melton, R., Kuhl, M., Johnson, D., Dunn, T., Lee, J., Foltz, F., & Garrick, R. (2018). Scholarship programs for vertical transfers in engineering and engineering

technology. *2018 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Salt Lake City, UT.

\*Hagler, L. & Sheridan, D. (2015). Exploring the academic and social experiences of Latino engineering community college transfer students at a 4-year institution: a qualitative research study. (Doctoral Dissertation). Retrieved from Northeastern University Digital Repository.

Higgins, J. & Green, S. (Eds). (2011). Chapter 4: Guide to the contents of a Cochrane protocol review. *Cochrane Handbook for Systematic Reviews of Interventions*. The Cochrane Collaboration.

Hills, J. (1965) Transfer shock: The academic performance of the transfer student. *The Journal of Experimental Education*, Vol. 33, No. 3.

Hossler, D. & Bontrager, B. (2015). *Handbook of Strategic Enrollment Management*. San Francisco: Jossey-Bass an Imprint of Wiley.

Hossler, D., Shapiro, D., Dundar, A., Ziskin, M., Chen, J., Zerquera, D., & Torres, V. (2012). *Transfer and Mobility: A National View of Student Movement in Postsecondary Institutions, Fall 2006 Cohort (Signature Report No. 2)*. Herndon, VA: National Student Clearinghouse Research Center.

\*Hutton, R. & Panter, A. (2015). Modeling bachelor's degree completion rates of North Carolina community college transfer students using a discrete-time survival analysis. (Doctoral Dissertation). Retrieved from the University of North Carolina.

\*Illinois Community College Board. (1986). *Transfer study: a five-year study of students transferring from Illinois two-year colleges to Illinois senior colleges/universities in the fall of 1979*. Springfield, IL: U.S. Department of Education. Retrieved from <https://eric.ed.gov/?id=ED270148>.

- Institute for Education Sciences, National Center for Education Statistics. (2013.) Percentage of recent high school completers enrolled in 2-year and 4-year colleges, by income level: 1975 through 2012. Available at [http://nces.ed.gov/programs/digest/d13/tables/dt13\\_302.30.asp](http://nces.ed.gov/programs/digest/d13/tables/dt13_302.30.asp).
- Ishitani, T. (2008). How do transfers survive after “transfer shock”? A longitudinal study of transfer student departure at a four-year institution. *Research in Higher Education*, 49, 403-419.
- \*Ivins, T., Copenhaver, K., & Koclanes, A. (2017). Adult transitional theory and transfer shock in higher education: practices from literature. *Reference Services Review*. Vol. 45, Issue 2, pp. 244-257. doi.org/10.1108/RSR-08-2016-0048
- \*Jackson, D. & Laanan, F. (2014). Desiring to fit: Fostering the success of community college transfer students in STEM. *Community College Journal of Research and Practice*. Vol. 29, No. 2, pp. 132-149.
- \*Jackson, D., Starobin, S., & Laanan, F. (2013). The shared experiences: facilitating successful transfer of women and underrepresented minorities in stem fields. *New Directions for Higher Education*. Vol. 2013, No. 162, pp. 69-76.
- \*Jacquez, R., Garland, J., King, J., Auzenne, M., Peralta, S., & Rubio, H. (2005). The minority engineering transfer and articulation (META) program: building stronger pathways and developing student achievement. *2005 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Portland, OR.
- \*Jefferson, G., Steadman, S. & Dougherty, F. (2013). Transfer student transition: Lessons learned. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.

- \*Jones, S. & Waggenpack, W. (2015). BRCC to LSU engineering pathway to success. *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- \*Jovanovic, V., Sparkman-Key, N., Cigularov, K., Cigularova, D., & Anthony, B. (2018). Advancing the engineering field: Opportunities to support transfer students. *2018 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Salt Lake City, UT.
- \*Kampe, J., Edmister, W., Boone, C., & Watford, B. (2008). Transfer students: tailoring a freshman program to their needs. *2008 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Pittsburgh, PA.
- Kanter, M., Ochoa, E., Nassif, R., & Chong, F. (2011). Meeting President Obama's 2020 College Completion Goal. Lecture presented at Department of Education. Retrieved from <https://www.ed.gov/news/speeches/meeting-president-obamas-2020-college-completion-goal>.
- \*Knight, D, Bergom, I. Burt, B., & Lattuca, L. (2014). Multiple starting lines: pre-college characteristics of community college and four-year institution engineering students. *2014 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Indianapolis, IN.
- Knowles, M., Holton, E., & Swanson, R. (2005). *The adult learner: the definitive classic in adult education and human resource development*. Amsterdam: Elsevier.
- Laanan, F. (2004). Studying transfer students, part 1: instrument design and implications. *Community College Journal of Research and Practice*. Vol 28, pp. 331–351.

- \*Laanan, F., Jackson, D., & Darrow, M. (2010). Experiences of engineering transfer students: from community college to university. *2010 American Society for Engineering Education (ASEE) Conference Proceedings*. Louisville, KY.
- \*Laanan, F., Jackson, D., & Rover, D. (2011). Engineering transfer students: characteristics, experiences, and student outcomes. *2011 American Society for Engineering Education (ASEE) Conference Proceedings*. Vancouver, B.C., Canada.
- \*Laier, J. & Steadman, S. (2014). Improving transfer student success. *2014 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Indianapolis, IN.
- \*Lakin, J. & Cardenas Elliott, D. (2016). STEMing the shock: examining transfer shock and its impact on stem major and enrollment persistence. *Journal of the First-Year Experience & Students in Transition*. Vol. 28, No. 2.
- \*Laugerman, M. & Shelley, M. (2013). A structural equation model correlating success in engineering with academic variables for community college transfer students. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.
- \*Laugerman, M., Rover, D., Shelley, M., & Mickelson, S. (2015). Determining graduation rates in engineering for community college transfer students using data mining. *International Journal of Engineering Education*. Vol. 31, No. 6, pp. 1448-1457.
- \*Laugerman, M., Shelley, M., Rover, D., & Mickelson, S. (2015). Estimating survival rates in engineering for community college transfer students using grades in calculus and physics. *International Journal of Education in Mathematics, Science and Technology*. Vol. 3, No. 4, pp. 313-321.

- \*Lee, H. & Schneider, T. (2016). Does post-transfer involvement matter for persistence of community college transfer students? *Community College Journal of Research and Practice*. Vol. 42, No. 2, pp. 77-94.
- \*Lockwood, P., Hunt, E., Matlack, R., & Kelley, J. (2013). From community college to four-year institution: a model for recruitment and retention. *Community College Journal of Research and Practice*. Vol. 37, No. 8, pp. 613.
- \*Lopez, C. & Jones, S. (2017). Examination of factors that predict academic adjustment and success of community college transfer students in stem at 4-year institutions. *Community College Journal of Research and Practice*. Vol. 41, No. 3, pp. 168-182.
- \*Lopez, C. & Laanan, F. (2012). Transfer students in STEM majors at a midwestern university: academic and social involvement factors that influence student success. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- Lundberg, T. (2014). Making space and making do: An exploration of the practices that start new majority students towards their educational goals. (Doctoral Dissertation). Retrieved from the University of Wisconsin at Madison.
- Manyaga, F., Sithole, A., & Hanson, S. (2017). Comparison of student retention models in undergraduate education from the past eight decades. *Journal of Applied Learning in Higher Education*. Vol. 7, pp. 29-41.
- \*Marra, R., Chia-Lin, T., Bogue, B., & Landa Pytel, J. (2015). Alternative pathways to engineering success -using academic and social integration to understand two-year engineering student success. *American Journal of Engineering Education*. Vol. 6, No. 2, pp. 69-84.
- \*Massi, L., Lancey, P, Nair, U, Straney, R. Georgiopoulos, M., & Young, C. (2012). Engineering and computer science community college transfers and native freshmen students: relationships

- among participation in extra-curricular and co-curricular activities, connecting to the university campus, and academic success. *2012 IEEE Frontiers in Education (FIE) Conference Proceedings*. Seattle, WA.
- \*Mattis, M. & Sislin, J. (2005). *Enhancing the community college pathway to engineering careers*. National Academies Press. Washington, DC.
- McBurnie, J., Campbell, M., & West, J. (2012). Avoiding the second year slump: A transition framework for students progressing through university. *International Journal of Innovation in Science and Mathematics Education*. Vol. 20. No. 2.
- \*McDowell, C. & Harrell, A. (2009). Easing the transition from the community college to the four-year university. *2009 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Austin, TX.
- \*Mendez, E. & Fraser-Abder, P. (2001). A qualitative case study of Hispanic community college students' transfer and first -year experiences in a college of engineering at a large research public university. (Doctoral Dissertation). Retrieved from the New York University Digital Repository.
- \*Mickelson, S. & Laugerman, M. (2011). Characteristics of community college transfer students that successfully matriculate and graduate in engineering. *2011 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Vancouver, B.C., Canada.
- \*Miguel, A. & Abraham, S. (2017). Creating an environment for transfer student success. *2017 American Society for Engineering Education (ASEE) Conference Proceedings*. Columbus, OH.
- \*Mobley, C. & Brawner, C. (2013). Engineering transfer students' views on orientation and advising. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.

- \*Mobley, C & Brawner, C. (2018). “Life prepared me well for succeeding”: The enactment of community college cultural wealth, experiential capital, and transfer student capital by first-generation engineering transfer students. *Community College Journal of Research and Practice*. Vol. 43, No. 5, pp. 353-369.
- \*Mobley, C., Shealy, E., & Brawner, C. (2013). First-generation engineering transfer students: a qualitative study of social and cultural capital. *2013 IEEE Frontiers in Education (FIE) Conference Proceedings*. Oklahoma City, OK.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D., & the PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine*. Vol. 141, No. 4, pp. 264-270.
- NACADA: The Global Community for Academic Advising. (2017). NACADA academic advising core competencies model. Retrieved from <https://www.nacada.ksu.edu/Resources/Pillars/CoreCompetencies.aspx>
- \*Ogilvie, A. (2014). A review of the literature on transfer student pathways to engineering degrees. *2014 American Society for Engineering Education (ASEE) Conference Proceedings*. Indianapolis, IN.
- \*Ohland, M. & Anderson, T. (2001). SUCCEED (Southeastern University and College Coalition for Engineering Education) Strategic Plan Revision. U.S. Department of Education
- \*Olson, L., Moll, A., Bullock, D., Jain, A., & Callahan, J. (2016). Support model for transfer students utilizing the STEM scholarship program. *2016 American Society for Engineering Education (ASEE) Conference Proceedings*. New Orleans, LA.

Pascarella, E., Smart, J., and Ethington, C. (1986). Long-term persistence of two-year college students. *Proceedings from the 1986 Study of Higher Education Conference*. San Antonio, TX.

President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Author.

\*Rendon, L. (1986). A comprehensive strategy to examine and address transfer education. *Conference of the Texas Coordinating Board Proceedings*. Austin, TX.

Rendon, L. (1994). Validating culturally diverse students toward a new model of learning and student development. *Innovative Higher Education*. Vol. 19, No. 1, pp. 33-51.

Rhoades, G. (1998). Reviewing and rethinking administrative costs. In J.C. Smart (Ed.). *Higher Education: Handbook of Theory and Research* 9, pp. 111-146. New York: Agathon Press.

\*Ryan, R. & Durdella, N., & Navarro, T. (2014). A case study of success: mentoring and supporting underrepresented transfer students in a mechanical engineering program. *2014 American Society for Engineering Education (ASEE) Conference Proceedings*. Indianapolis, IN.

\*Sarder, B. (2013). Bridging the gap in transition of students from community colleges to universities. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.

Schlossberg, N. (1984). *Counseling Adults in Transitions*. New York: Springer Publishing Company.

- \*Scott, T., Thigpin, S., & Bentz, A. (2017). Transfer learning community: overcoming transfer shock and increasing retention of mathematics and science majors. *Journal of College Student Retention: Research, Theory & Practice*. Vol. 19, No. 3, pp. 300-316.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Bhimdiwali, A., Nathan, A., & Youngsik, H. (2018). Transfer and Mobility: A National View of Student Movement in Postsecondary Institutions, Fall 2011 Cohort (Signature Report No. 15). Herndon, VA: National Student Clearinghouse Research Center.
- \*Shayevich, A., Goldberg, J., & Edson, J. (2008). Performance and retention of transfer engineering students. *2008 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Pittsburgh, PA.
- \*Sheinberg, B. (2015). An unanticipated outcome of undergraduate research experiences for community college students: Creation of a materials science and engineering educational program. *Materials Research Society*. Vol. 1762.
- \*Shields, N. & Pietroburgo, J. (2000). Comparing the success of two-year college students and students with other academic backgrounds in a non-traditional engineering program. *2000 American Society for Engineering Education (ASEE) Conference Proceedings*. St. Louis, MO.
- \*Skurla, C. & Eisenbarth, S. (2013). Scholarships for academic success program: a final report. *2013 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Atlanta, GA.
- \*Snyder, J. & Cudney, E. (2018). A retention model for community college STEM students. *2018 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Salt Lake City, UT.

- \*Starobin, S., Smith, D., & Laanan, F. (2016). Deconstructing the transfer student capital: intersect between cultural and social capital among female transfer students in stem fields. *Community College Journal of Research and Practice*. Vol. 40, No. 12, pp. 1040-1057.
- \*Sullivan, M., de Cohen, C., Barna, M., Orr, M., Long, R., & Ohland, M. (2012). Understanding engineering transfer students: demographic characteristics and educational outcomes. *2012 IEEE Frontiers in Education (FIE) Conference Proceedings*. Seattle, WA.
- Tobolowsky, B. & Cox, B. (2012). Rationalizing neglect: an institutional response to transfer students. *The Journal of Higher Education*. Vol. 83, No. 3, pp. 389-410.
- Thomas, J. & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*. Vol. 8, No. 45.
- Thorne, S., Jensen, L., Kearney, MH., Noblit, G., & Sandelowski, M. (2004). Qualitative meta-synthesis: reflections on methodological orientation and ideological agenda. *Qualitative Health Research*. Vol. 14, No. 10, pp. 1342-1365.
- Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition*. Second Edition. University of Chicago Press.
- \*Tkacik, P., Lim, J., Tolley, P., & Warren, K. (2012). Gendered socialization during the first semester: contrasting experiences of male and female transfer/non-traditional engineering students. *2012 American Society for Engineering Education (ASEE) Conference Proceedings*. San Antonio, TX.
- \*Townley, G., Katz, J., Wandersman, A., Skiles, B., Schillaci, M., Timmerman, B., & Mousseau, T. (2013). Exploring the role of sense of community in the undergraduate transfer student experience. *Journal of Community Psychology*. Vol. 41, No. 3, pp. 277-290.

- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of a systematic review. *British Journal of Management*. Vol. 14, pp. 207 – 222.
- Western Interstate Commission for Higher Education (WICHE). (2016). *Knocking at the College Door: Projections of High School Graduates*. Retrieved February 2019 from <https://static1.squarespace.com/static/57f269e19de4bb8a69b470ae/t/58d2eb93bf629a4a3878ef3e/1490217882794/Knocking2016FINALFORWEB-revised021717.pdf>
- \*Wetzel, L. & Debure, K. (2018). The role of faculty in fostering stem transfer student success. *Journal of College Science Teaching*. Vol. 47, No. 4, pp. 42-46.
- \*Whang, L., Tawatao, C., Danneker, J., Belanger, J., Edward Weber, S., Garcia, L., & Klaus, A. (2017). Understanding the transfer student experience using design thinking. *Reference Services Review*. Vol. 45, No. 2, pp. 298-313.
- Wilder, J. (1993). A sophomore slump: A complex developmental period that contributes to attrition. *College Student Affairs Journal*. Vol. 12, No. 2, pp. 18-27.
- \*Yoon Yoon, S. Cortez, M., Imbrie, P., & Reed, T. (2018). A comparative study of student success between first-time-in-college and first-time-transfer engineering students. *International Journal of Engineering Education*. Vol. 34, No. 1, pp. 69-87.
- \*Zamudio, R. & Davis, S. (2015). From community college to 4-year institutions: Latinas' successful completion of STEM baccalaureate degrees. (Doctoral Dissertation). Retrieved from California State University.

Table 4.4 Coding Framework

<b>Code</b>	<b>Description</b>
<i>Student Characteristics</i>	
Demographics	Race; ethnicity; gender; age
Financial need	Financial need of student (often in terms of socioeconomic status (SES), parent income, etc.)
Financial aid	Amount of financial aid received (primarily in the form of a scholarship, but could be loans as well)
<i>Pre-Transfer</i>	
Sending institution academic credentials	Number of credits completed; overall GPA; core engineering credits completed; degree completion
<i>Post-Transfer Academics</i>	
GPA	First term and second term at receiving institution
Credit hours	Number of hours completed in first term and second term
<i>Engagement</i>	
Academic engagement	Faculty and peer mentoring; professional organizations; undergraduate research, learning communities; study groups
Social engagement	Student organizations; intramural sports; volunteer work; networking with other transfer students
<i>Motivation</i>	
Personal motivation	Intrinsic motivation to be an engineer; problem-solving; help others
<i>Academic Advising</i>	
Transfer specific Orientation	Dedicated transfer advising Transfer-focused orientation
<i>Mentoring</i>	
Peer mentoring	Peer mentoring at receiving institution
Faculty mentoring	Faculty mentoring at receiving institution
<i>Belonging</i>	
Campus connection	Connection to the resources and support, as well as amenities on campus
Sense of community	Connection with other students and feeling welcomed and included
<i>Framework and Population</i>	
Theory/Framework	Student retention theories; other theories applied to this literature

Student population

Engineering transfers, STEM transfers, specific engineering discipline transfers; female engineering transfers; Latina engineering transfers; black engineering transfers; first-year and transfer engineers

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Appendix B

Table 4.5 Factors Impacting Engineering Transfer Student Persistence

<sup>1</sup> Student-Influenced Factor

<sup>2</sup> Institution-influenced Factor

<sup>3</sup> Student-Influenced and Institution-Influenced Factor

No.	Factor	Number of Papers	Description
1.	<sup>2</sup> Specialized transfer advising (at receiving institution)	49 (60%)	The existence of academic advising provided specifically to transfer students at the receiving institution (e.g., transfer center, dedicated transfer advisor, etc.).
2.	<sup>1</sup> Scholarship recipient (at receiving institution)	20 (24%)	The receipt of a scholarship to attend the receiving institution.
3.	<sup>2</sup> Peer mentoring (at receiving institution)	18 (22%)	The availability of a formal peer mentoring program at the receiving institution.
4.	<sup>3</sup> Level of social integration (at receiving institution)	15 (18%)	The extent to which the student socially integrates themselves into the receiving institution (e.g., extra-curricular opportunities, forming study groups, etc.)
5.	<sup>1</sup> Student demographics	13 (16%)	Gender, race, ethnicity, and age
6.	<sup>1</sup> Number of credit hours completed (at sending institution)	11 (13%)	The total number of credits hours completed by the student at the sending institution.
7.	<sup>2</sup> Transfer orientation (at receiving institution)	9 (11%)	The availability of a transfer specific orientation at the receiving institution.
8.	<sup>2</sup> Faculty mentoring (at receiving institution)	9 (11%)	The availability of faculty mentoring at the receiving institution.
9.	<sup>3</sup> Level of interaction with faculty (at receiving institution)	8 (10%)	The extent to which the student interacts with faculty at the receiving institution.
10.	<sup>1</sup> Overall GPA (at sending institution)	8 (10%)	The final grade point average (GPA) of the student at their sending institution.
11.	<sup>1</sup> Completion of associate degree (at sending institution)	7 (9%)	Student completed an associate degree at a 2-year institution.

No.	Factor	Number of Papers	Description
12.	<sup>2</sup> Supportive campus environment (at receiving institution)	6 (7%)	The degree to which the student feels the campus environment is supportive of transfer students.
13.	<sup>1</sup> Core engineering courses completed (at sending institution)	6 (7%)	The completion of core engineering curriculum courses at the sending institution (i.e., calculus, chemistry, physics, etc.).
14.	<sup>3</sup> Motivation	6 (7%)	Whether a student's motivation is based on an intrinsic desire to problem solve or based on a perception of the prestige of engineering.
15.	<sup>3</sup> Level of interaction with peers (at receiving institution)	5 (6%)	The extent to which the student interacts with peers at the receiving institution.
16.	<sup>1</sup> Parent's level of education	5 (6%)	The highest level of education earned by the student's parent(s).
17.	<sup>3</sup> First fall credit hours (at receiving institution)	4 (5%)	The total credit hours a student attempted in their first fall semester.
18.	<sup>3</sup> GPA in core courses (at receiving institution)	4 (5%)	The GPA a student earns in the core engineering courses at the receiving institution.
19.	<sup>3</sup> Participation in undergraduate research (at receiving institution)	4 (5%)	The student's participation in undergraduate research at the receiving institution.
20.	<sup>3</sup> Level of campus involvement (at receiving institution)	3 (4%)	The student's level of campus involvement at the receiving institution.
21.	<sup>2</sup> Mid-semester grades review (at receiving institution)	3 (4%)	The university's usage of mid-semester grades in the student's first term of enrollment at the receiving institution.
22.	<sup>3</sup> First fall GPA (at receiving institution)	2 (2%)	The student's GPA at the end of their first fall semester at the receiving institution.
23.	<sup>1</sup> High school class rank	1 (1%)	The student's final class rank within the graduating high school class.

<b>No.</b>	<b>Factor</b>	<b>Number of Papers</b>	<b>Description</b>
24.	<sup>3</sup> Participation in learning communities (at receiving institution)	2 (2%)	The student's participation in a learning community at the receiving institution.
25.	<sup>1</sup> Financial need	2 (2%)	The level of financial aid the student needs.
26.	<sup>3</sup> Number of hours worked per week (at receiving institution)	2 (2%)	The number of hours per week the student is employed.
27.	<sup>3</sup> Degree goals	1 (1%)	The student's ultimate degree goal (associate, bachelor, graduate).
28.	<sup>3</sup> First spring credit hours (at receiving institution)	1 (1%)	The total credit hours the student attempted in their first spring semester.
29.	<sup>3</sup> First spring GPA (at receiving institution)	1 (1%)	The student's GPA at the end of their first spring semester at the receiving institution.
30.	<sup>2</sup> Information available on internet (at receiving institution)	1 (1%)	The usefulness of the receiving institution's website in terms of academic advising information.
31.	<sup>2</sup> Right to fail policies (at receiving institution)	1 (1%)	Existence of policies requiring students to attend class, meet with an advisor, and earn a minimum grade in specific courses.
32.	<sup>2</sup> Sending institution accreditation	1 (1%)	The ABET accreditation status of the sending institution.
33.	<sup>1</sup> Residency	1 (1%)	The residency status of the student (in-state or out-of-state).
34.	<sup>1</sup> Withdrawing from a course (at receiving institution)	1 (1%)	The number of courses a transfer student withdraws from in their first term at the receiving institution.

## Chapter 5

### Institutional Analysis

(Manuscript 3: Comparison of Transfer Shock and Graduation Rates Across Engineering Transfer Student Populations)

#### 5.1 Abstract

**Background** Increasing the number of engineering graduates continues to be a national priority. As the number of transfer students continues to increase, this population provides another avenue for institutions to meet this priority. Many engineering transfer students experience transfer shock, which refers to a decrease in a student's grade point average (GPA) as compared to their sending institution GPA. Transfer shock can lead to transfer students leaving the institution, and is more prevalent in engineering transfer students.

**Purpose** The purpose of this study is to analyze a single institutional dataset to determine when transfer shock occurs, how it differs between engineering transfer student sub-groups, and if transfer shock is a predictor of graduation within four years in engineering.

**Scope/Method** A 10-year dataset with 789 engineering transfer students was categorized into four transfer student sub-groups (lateral in-state transfers, lateral out-of-state transfers, vertical transfers with an associate degree, and vertical transfers with no associate degree) to understand differences between transfer shock values in the first three terms of enrollment and graduation rates.

**Results** Engineering transfer students experience a decrease in term GPA compared to their transfer GPA in their first three terms. Rather than a transfer shock, these students experience a

transfer adjustment. Additionally, the engineering transfer student sub-groups experience different levels of transfer adjustment, which is a predictor of their 4-year graduation rates.

**Conclusions.** There are significant differences in the transition experience across the engineering transfer student sub-groups. More strategic programming and policies are needed to address the varying needs of each of the engineering transfer student sub-groups.

**Keywords** transfer student; persistence; regression

## 5.2 Introduction

Pascarella, Smart, and Ethington (1986) define persistence as actively working toward a bachelor's degree within a nine-year period. Student persistence within engineering has received much attention over the last several decades. However, the American Society of Engineering Education (ASEE) reports that graduation rates of engineering students have minimally changed (ASEE, 2017). A recent report from the Western Interstate Commission for Higher Education (WICHE) predicts there will be a decline in the number of high school graduates over the next decade (WICHE, 2017). As the United States (U.S.) aims to increase the number of engineering graduates, the WICHE projection further emphasizes the importance of persistence in engineering.

The ASEE report is based on first-time, full-time students (FTFT); information is not collected on a national level for engineering transfer students. Transfer students are defined as those attending more than one institution on their route to a bachelor's degree, and represent a growing trend in the U.S. (Brawner & Mobley, 2016; Habley, Bloom, & Robbins, 2012). From 2012 to 2017, the National Student Clearinghouse (NSC) reported a 2% increase in vertical transfers, which are students that begin at a 2-year institution and transfer to a 4-year institution

(Shapiro, Dundar, Huie, Wakhungu, Bhimdiwali, Nathan, & Youngsik, 2018). They also report a 4% increase in lateral transfers, which are students who begin at a 4-year institution and transfer to another 4-year institution (Shapiro et al., 2018). With less students expected to enter engineering programs, and more students completing a transfer, understanding engineering transfer student persistence should also be a focus for engineering education and enrollment management.

Transfer shock refers to a decrease in grade point average (GPA) that students commonly experience when transitioning to a new institution (Hills, 1965). The existing literature on engineering transfer students discusses the increased prevalence of transfer shock in engineering students (Anderson-Rowland, 2011). Lakin and Cardenas Elliott (2016) demonstrated transfer shock was even more common in engineering transfer students completing a vertical transfer. Researchers find this to be a strong predictor of transfer students falling below a 2.0 overall GPA and being placed on academic probation after their first post-transfer term (Graham & Dallam, 1986; Lakin & Cardenas Elliott, 2016). Researchers also find transfer shock is a strong predictor of transfer students leaving the institution before graduation (Glass & Harrington, 2002; Ishtani, 2008).

This paper analyzes a 10-year institutional dataset of engineering transfer students at a large public southeastern research institution where this population represents approximately 14% of the institution's incoming engineering students each year. The analysis provides comparisons of transfer shock across three terms and four engineering transfer student sub-groups, as well as if it is a predictor of 4-year graduation rates in engineering.

### 5.3 Background

The engineering transfer student population gained traction in the literature in the 2000's. Early research focused on student factors, however, there has been a noticeable shift in the research in

the last decade. Researchers began to also focus on identifying institutional practices and understanding the role of the receiving institution as a responsible party in the graduation of these students. In a systematic review of the existing literature on engineering transfer students, Authors (Under Review) identified 34 factors affecting engineering transfer student persistence. Table 5.1 highlights the most frequently reported factors.

Table 5.1. Common Factors of Engineering Transfer Student Persistence (Authors, Under Review)

<b>Factor</b>	<b>Reference</b>
Student demographics: gender, race, ethnicity, and age	Shields & Pietroburgo, 2000 Tkacik, Lim, Tolley, & Warren, 2012
Number of credits earned prior to transferring	Lopez & Laanan, 2012 Mattis & Sislin, 2005 Shields & Pietroburgo, 2000
Completion of an associate degree	Darrow & Laanan, 2012 Hutton & Panter, 2015
Student's overall GPA from their sending institution	Anderson-Rowland, 2000 Lopez & Laanan, 2012 Shields & Pietroburgo, 2000
GPA in core engineering	Laugerman & Shelley, 2013 Laugerman, Shelley, Rover, & Mickelson, 2015
Dedicated transfer advising	Jones & Waggenspack, 2015 Laier & Steadman, 2014 Mattis, Lancey, Nair, Straney, Georgiopoulos, & Young, 2012 Sarder, 2013
Transfer-focused orientation	Anderson-Rowland, 2013 Auerbach & Williams, 2013 Brawner & Mobley, 2016 Ivins, Copenhaver, & Koclanes, 2017 Jackson & Laanan, 2013
Supportive campus environment	Darrow & Laanan, 2012

Number of credits a student takes in their first post-transfer term	Anderson-Rowland, 2009 Laier & Steadman, 2014 Lakin & Cardenas Elliott, 2016 Laugerman & Shelley, 2013
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Despite the identification of factors that affect the success of engineering transfer students, there are limitations to the existing research. The literature primarily focuses on students completing a vertical transfer (Authors, Under Review). However, the 2018 NSC report shows students are completing lateral transfers at a rate nearly equal to vertical transfers (Shapiro et al., 2018). Additionally, the literature primarily reviews the post-academic performance during the first post-transfer year. Authors (Under Review) indicate academic performance after the first post-transfer term should be further explored to identify additional ways to increase graduation rates for this population. This aligns with literature supporting a continuous review of FTFT students past their first year of enrollment (Wilder, 1993; McBurnie, Campbell, & West, 2012), and can lead to additional insights on the experiences of engineering transfer students as they progress through the engineering curriculum.

Using Tinto's (1993) student integration model as its theoretical framework, this study examined several variables to determine any significant differences in transfer shock and 4-year graduation rates for vertical and lateral engineering transfer students. Individual attributes are evaluated, and are operationalized as student demographics that are measured as gender, race, and ethnicity. Prior schooling is evaluated and operationalized as pre-transfer academics, and is measured as transfer GPA and transfer student type. Academic performance is evaluated and operationalized as transfer shock, and is measured as the difference between the students' transfer GPA and the GPA at their receiving institution at the end of each of the first three post-transfer terms.

#### 5.4 Research Objectives

Retention of engineering students is a well-researched area, but the focus has primarily been on FTFT students. The research on transfer students is growing, but mainly focuses on increasing access through transfer pathways from a 2-year institution to a 4-year institution. Our research analyzes a single-institution longitudinal dataset to demonstrate similarities and differences between transfer shock and graduation rates of vertical and lateral transfer students. A 4-year graduation rate is used for comparison, which aligns with findings by Ohland, Camacho, Layton, Lord, and Wasburn (2009), who indicate a 4-year persistence rate is highly predictive of six-year graduation rates.

A preliminary analysis of the engineering transfer students at the institution studied served as the catalyst for this research. Literature supports vertical transfer students with an associate degree persist at higher rates than those without an associate degree (Darrow & Laanan, 2012; Hutton & Panter, 2015). Several of the state community colleges have a large population of engineering transfer students that will attend the previously described institution. The community colleges requested an analysis of their students with an associate degree and those without to determine if those with an associate degree were persisting at higher rates. As the data were analyzed, it became clear there was a sizeable population of lateral transfer students, both in-state and out-of-state. Cosentino, Sullivan, and Gahlawat (2014) demonstrated in-status status was a significant variable when modeling graduation of engineering transfer students. Therefore, this paper examines transfer shock and 4-year graduation rate differences between four sub-groups of engineering transfer students, as described in Table 5.2. Disaggregating these data provides a better understanding of the experiences of engineering transfer students and how they may differ across the sub-groups. Additionally, this research seeks to expand beyond considering transfer

shock in only the first post-transfer term, and focuses on changes in term GPA across the first three post-transfer terms of enrollment.

Table 5.2. Transfer Student Types

<b>Transfer Student Sub-Group</b>	<b>Definition</b>	<b>Abbreviation</b>	<b>Number of Students</b>
Vertical with associate degree	Student attended a 2-year institution and received an associate degree prior to transferring.	VAD	95
Vertical with no associate degree	Student attended a 2-year institution and did not receive an associate degree prior to transferring.	VNAD	465
Lateral in-state	Student attended a 4-year institution in the same state as their receiving institution.	LIS	127
Lateral out-of-state	Student attended a 4-year institution in a different state than their receiving institution.	LOS	102

This study explores four research questions related to these topics. First, does transfer shock extend beyond the first post-transfer term? Second, do the sub-groups of engineering transfer students experience differing levels of transfer shock? Third, are there variations in 4-year graduation rates across the sub-groups of engineering transfer students? Lastly, is transfer shock a predictor of 4-year graduation rates within engineering?

## 5.5 Methods

Data on all students enrolled at the institution from 2009-2018 were provided by the University Registrar's Office and the Office of Institutional Research. These datasets were merged for a comprehensive historical dataset that included student demographics, admissions information, transfer credits and institutions, and institutional enrollment data. The institutional enrollment data

provided a history of the student's progression through the institution including their major each term, as well as their graduation major and date when applicable. Only students admitted as engineering transfer students were considered for this analysis resulting in 2,589 students in the initial dataset. However, this analysis considers graduation rates in four years, therefore, only cohorts admitted 2009-2014 could be used, which decreased the total students to 1,233.

Several variables were calculated or determined and added to the dataset prior to analysis. First, each student was categorized by their engineering transfer student sub-group. This was determined by reviewing the students' sending institution and their transfer degree tag. Some students attended multiple sending institutions. In those situations, the sending institution used to determine the sub-group was selected by using the sending institution providing the highest number of credit hours for that student. Each identified sending institution was researched to determine whether it was a 2-year or 4-year institution. Those that attended a 2-year institution with a noted associate degree were coded as VAD (vertical associate degree). Those with no associate degree were coded as VNAD (vertical with no associate degree). Any sending institution not identified as a 2-year institution was reviewed for lateral transfer status. Students from sending institutions located in the same state as the receiving institution were coded as LIS (lateral in-state) and those from out-of-state were coded as LOS (lateral out-of-state).

The second added variable was each student's graduation status. A multi-step approach was used for this coding. The initial step included determining if the student graduated from engineering and how many years were completed to accomplish this. For those that did not graduate with an engineering major, the historical dataset was used to determine if they continued enrollment past four years or stopped prior to the fourth year, with appropriate coding for each. In

this study there was no differentiation between a student leaving engineering or leaving the institution, both were coded as “did not graduate in engineering.”

The next step added three variables by calculating the term GPA for each student’s first, second, and third post-transfer term of enrollment. Summer enrollment was not included; thus, only fall and spring terms with 12 or more credits hours were considered a term. Finally, three more variables, shown in Table 5.3, were added to compare the calculated term GPA to the GPA students had at their sending institution at the time of application. These variables measured transfer shock in the first three post-transfer terms. Transfer shock variables were not able to be computed for 77 students because the students were not enrolled in 12 or more credit hours in their first post-transfer term of enrollment. An additional 367 did not have a transfer GPA available. This resulted in 444 students being excluded for a total of 789 students in the final dataset.

Table 5.3 Transfer Shock Measurements (TSM)

TSM 1	First Post-Transfer Term GPA – Transfer GPA
TSM 2	Second Post-Transfer Term GPA – Transfer GPA
TSM 3	Third Post-Transfer Term GPA – Transfer GPA

Statistical analyses were conducted using Microsoft Excel and XLSTAT to investigate the differences in transfer shock and 4-year graduation rates between the engineering transfer student sub-groups. A one-way analysis of variance (ANOVA) was used to determine if a significant difference existed between the means of the sub-groups with TSM 1, TSM 2, and TSM 3 as dependent variables (Freedman, 2005). Post-hoc analyses, including the Bonferroni adjustment, were also conducted for pairwise comparison of the variables. Next, a chi-square test of independence was used to understand the difference between the frequencies of students across the sub-groups and 4-year graduation rate (McHugh, 2013). Logistic regression was then used to

explore if transfer shock is a predictor of graduation. This method was selected based on its ability to incorporate transfer shock measurements as continuous independent variables and a binary dependent variable of graduated or did not graduate (Tabachnick & Fidell, 2013).

## 5.6 Results

### 5.6.1 Descriptive Statistics

To provide justification for the selected methods of statistical analyses, as well as an overview of the data, descriptive analyses were conducted. Table 5.4 provides results related to the skewness and kurtosis, which indicates the data is normally distributed (Mohd Razali & Wah, 2011). A histogram plot of each data set also confirmed the normality of the data.

Table 5.4. Normality Tests

<b>Variable</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Skewness</b>	<b>Kurtosis</b>
Transfer GPA	3.46	0.36	-0.45	0.20
TSM 1	-0.50	0.66	-0.87	2.31
TSM 2	-0.58	0.70	-0.79	1.38
TSM 3	-0.53	0.71	-0.75	1.65

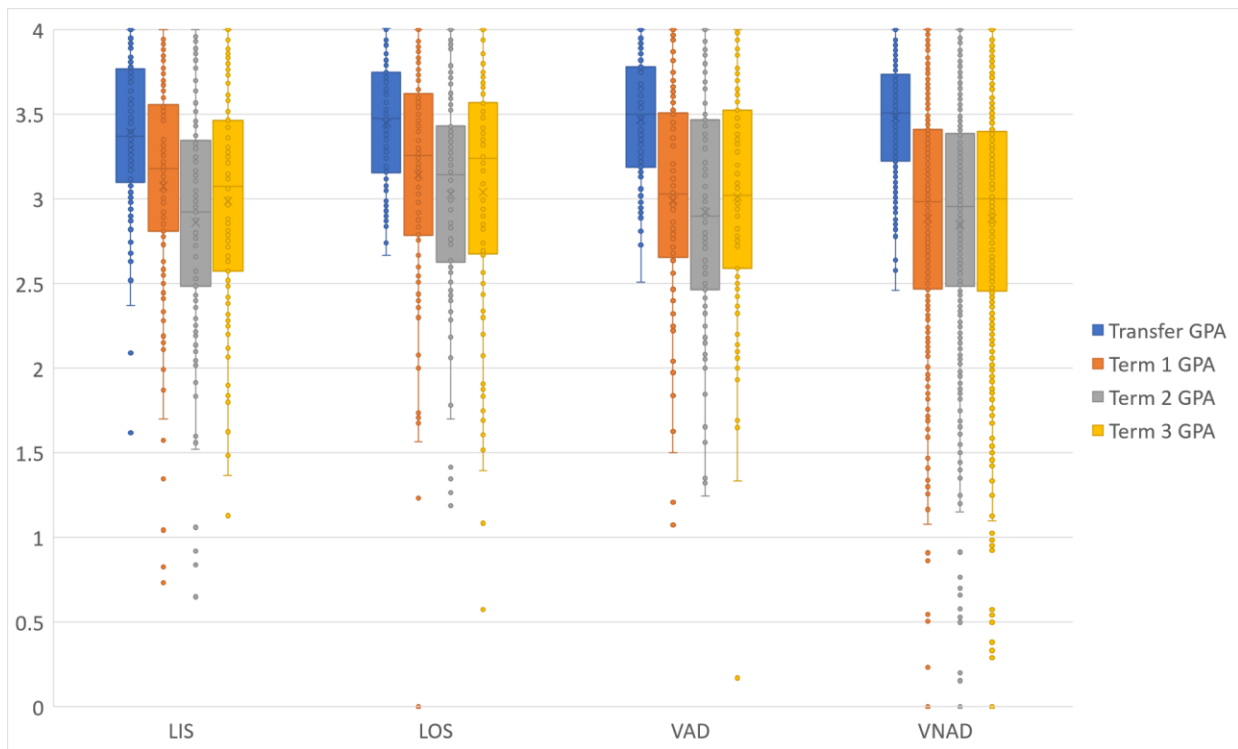
The demographics of each student type was also reviewed, and presented in Table 5.5. White is the most representative, with 61%. The second and third most represented ethnicity/race were Asian (13%) and Not Reported (12%). Additionally, 89% of the engineering transfer students in this dataset were male.

Table 5.5 Student Demographics

<b>Demographics</b>	<i>n</i>	%
<i>Race/Ethnicity</i>		
American Indian or Alaska Native	--	--
Asian	105	13%
Black or African American	26	3%
Hispanic (of any race)	46	6%
Nonresident Alien	69	9%
Not Reported	92	12%
Two or more races	33	4%
White	478	61%
<i>Gender</i>		
Male	704	89%
Female	83	11%
Not Reported	--	--
<i>First-Generation</i>	224	28%

The transfer GPA and term GPA in the first three post-transfer terms were reviewed across the sub-groups to understand if there were apparent differences. Figure 5.1 shows the transfer GPAs for each sub-group have very similar distributions, however, there is variation in the term GPAs. Lateral transfer students have higher GPAs in the first post-transfer term than the vertical transfer students. The lateral students have more variation during the first three post-transfer terms than the vertical students. The second post-transfer term has the lowest GPAs for each student type. This indicates that students are not only experiencing transfer shock in their first post-transfer term of enrollment, but that this phenomenon extends into subsequent terms.

Figure 5.1 Box Plots of Transfer GPA and Term GPAs by Student Type



### 5.6.2 Research Questions

To investigate whether transfer shock extends beyond the first post-transfer term, transfer shock measurements were determined for the first three post-transfer terms of enrollment at the receiving institution. The measurements were computed by finding the difference between students' GPA at the time of transfer and their term GPA in their first, second, and third post-transfer terms. Cumulative GPAs at the receiving institution were not used, only the specific term GPA in the first three terms. Table 5.6 provides a summary of the mean and standard deviation for each transfer shock measurement. Negative values indicate the mean GPA in that term was below the transfer GPA.

Table 5.6. Transfer Shock Measurements Mean and Standard Deviations

<b>Transfer Shock Measurement</b>	<b>Mean</b>	<b>Standard Deviation</b>
TSM 1	-0.50	0.66
TSM 2	-0.58	0.70
TSM 3	-0.53	0.71

In the first post-transfer term of enrollment, on average, students had a GPA that was 0.50 points less than their transfer GPA. Given a standard deviation of 0.66, in the first post-transfer term most students earned between 1.82 points lower and 0.82 points higher than their transfer GPA. In the second post-transfer term of enrollment, on average, students had a term GPA that was 0.58 points less than their transfer GPA. Given a standard deviation of 0.70, in the second post-transfer term most students earned between 1.98 points lower and 0.82 points higher than their transfer GPA. In the third post-transfer term of enrollment, on average, students had a term GPA that was 0.53 points less than their transfer GPA. Given a standard deviation of 0.71, in the third post-transfer term most students earn between 1.95 points lower and 0.89 points higher than their transfer GPA. These findings indicate that transfer shock is not a singular occurrence that happens in the first post-transfer term, this phenomenon continues into the second and third post-transfer terms of enrollment. The standard deviations are high indicating there is a significant amount of variation in student performance. The second post-transfer term has the highest level of transfer shock of the first three terms, which further supports transfer shock continuing past the first post-transfer term.

To better understand possible differences in transfer shock for each sub-group, TSM values were computed for each. Table 5.7 provides a summary of the mean and standard deviation for each measurement across the sub-groups.

Table 5.7 Transfer Shock Measurements Mean and Standard Deviation (Std. Dev.)

<b>Transfer Student Type</b>	<b>TSM 1 Mean (Std. Dev.)</b>	<b>TSM 2 Mean (Std. Dev.)</b>	<b>TSM 3 Mean (Std. Dev.)</b>
LIS	-0.32 (0.70)	-0.53 (0.70)	-0.41 (0.69)
LOS	-0.30 (0.70)	-0.42 (0.64)	-0.41 (0.72)
VAD	-0.48 (0.58)	-0.55 (0.69)	-0.46 (0.62)
VNAD	-0.60 (0.63)	-0.63 (0.71)	-0.60 (0.72)

All of the engineering transfer student sub-groups have a mean GPA that is less than their transfer GPA in each of the first three post-transfer terms. The second post-transfer term is consistently the most problematic for each student type. The lateral transfer students appear to perform better in all three post-transfer terms. Their first post-transfer semester has the least amount of transfer shock; however, they experience a large drop in their second post-transfer term. The lateral students' third post-transfer term has some improvement compared to their second post-transfer term, but they do not do as well as they did in the first post-transfer term. The VAD students perform worse in the first post-transfer term than the lateral students, but better than VNAD students. The second post-transfer term for VAD students declines, however, by the third post-transfer term performed slightly better than they did in the first post-transfer term. The VNAD students have the most transfer shock in the first post-transfer term and see very little variation in the subsequent terms.

A one-way ANOVA test was conducted on each transfer shock measurement to determine if there are significant differences in transfer shock across the sub-groups. A significant difference was found for TSM 1 ( $F(3, 785) = 9.87, p < 0.05$ ), indicating that the difference between the transfer shock in the first post-transfer term across the sub-groups is not due to chance, but due to the engineering transfer student sub-group. There were similar findings for TSM 2 ( $F(3, 785) = 2.93$ ) and TSM 3 ( $F(3, 785) = 3.98$ ), both at the  $p < 0.05$  level.

To further understand where the differences occurred, a post-hoc analysis was conducted using a two-tailed t-test with the Bonferroni adjustment on each pair. Findings show in the first post-transfer term, the transfer shock is significantly different between LIS and VNAD students, as well as LOS and VNAD students, both with small effect sizes. In the second post-transfer term, the transfer shock is significantly different between LOS and VNAD students with a small effect size. In the third post-transfer term, the transfer shock is significantly different between LIS and VNAD students with a small effect size. These findings show there is a significant difference between the lateral students and VNAD students. The VAD students were not found to be significantly different from the lateral students or the VNAD students. Lateral students have lower transfer shock measurements across all three post-transfer terms, and VNAD students have the highest measurements, with VAD students in the middle.

An additional one-way ANOVA was conducted on the transfer GPA for each of the sub-groups. The results indicate no significant difference in the students' transfer GPA ( $F(3, 785) = 2.04$ ), which provides further evidence that the engineering transfer student sub-groups do experience different levels of transfer shock, independent of their transfer GPA. The lateral students have the least amount of shock overall. The VAD students seem to adapt the most across the first three post-transfer terms, though they still do not perform as well as lateral transfer

students. Additionally, VNAD students consistently experience the highest level of transfer shock across the first three post-transfer terms, and do not show significant improvement. This is an important finding for institutions that aim to develop programming specific to engineering transfer students. The programming needs to extend beyond the initial transition term and may be different for each of the identified sub-groups of engineering transfer students.

To determine if differences in 4-year graduation rates exists across the engineering transfer student sub-groups, chi-square analysis was used. Table 5.8 provides the 4-year graduation rates across each sub-group, and those that did not graduate.

Table 5.8 Persistence Rates Across Transfer Student Types

<b>Transfer Student Type</b>	<b>4-Year Graduation Rate</b>	<b>Did not Graduate Engineering within 4 Years</b>
LIS	107 (84%)	20 (16%)
LOS	83 (81%)	19 (19%)
VAD	74 (78%)	21 (22%)
VNAD	335 (72%)	130 (28%)

These data indicate that lateral engineering transfer students have a higher 4-year graduation rate than vertical engineering transfer students. Of the vertical engineering transfer students, VAD students graduated at higher rates. The chi-square analysis confirms that there is a significant difference ( $p < 0.05$ ) between the transfer student types. This is an important finding as Table 5.8 shows the VNAD students make up the majority of transfer students at this institution, but have the lowest graduation rates. It's important to better understand why this population struggles more than the other engineering transfer student sub-groups, and create policies or programming to positively influence their graduation rates.

Findings from the previous questions indicate lateral transfer students experience less transfer shock and have higher 4-year graduation rates. To determine if transfer shock is a predictor

of 4-year graduation rates, we used logistic regression. The variables included were transfer GPA, transfer student type, the three transfer shock measurements, and student demographics. Table 5.9 provides the odds ratios for each model, as well as multiple R<sup>2</sup> values and Akaike information criterion (AIC) (Field, Miles, Field, 2012).

Table 5.9 Logistic Regression Results (Odds Ratio) for Graduated Engineering in Four Years

<b>Variable</b>	<b>Model 1</b>	<b>Model 2</b>	<b>Model 3</b>	<b>Model 4</b>	<b>Model 5</b>
<b>Transfer GPA, SD: 0.36</b>	1.73*	1.90**	1.82*	4.99**	5.00**
<b>Transfer Student Type</b>					
LIS		2.23*			1.93*
LOS		1.74*			1.02
VAD		1.38			1.14
<b>Student Demographics</b>					
Female			1.39		1.43
Gender Not Reported			0.27		0.29
American Indian or Alaska Native			0.94		0.33
Asian			0.73		0.75
Black or African American			1.08		1.11
Hispanics of any race			1.32		1.18
Nonresident Alien			1.10		1.44
Race Not Reported			0.46*		0.69
Two or more race			1.14		0.86
Out-of-State			1.24		1.06
<b>Transfer Shock</b>					
TSM 1, SD: 0.66				2.75**	2.59**
TSM 2, SD: 0.70				2.29**	2.24**
TSM 3, SD: 0.71				1.87**	1.81**
<b>Model Fit</b>					
Cox and Snell	0.01	0.02	0.09	0.21	0.30
Nagelkerke	0.01	0.03	0.14	0.31	0.44
AIC	869	886	817	697	629

Odds ratio indicates the likelihood of graduating from engineering relative to students that do not graduate for each one-unit decrease in standard deviation of the independent variables. Values below 1 indicate a lower likelihood of graduating with an engineering degree in four years. \*p<0.05, \*\*p<0.01

The reference groups for the control variables are VNAD students, male students, white students, in-state students, and those that did not graduate within four years. As an example

interpretation, in model 5, LIS students are 93% more likely to graduate than VNAD students (odds ratio of 1.93). Additionally, Asian students are 25% less likely to graduate than White students (odds ratio of 0.75). For the continuous variables, the odds ratio should be interpreted using a one-unit change in the standard deviation of the variable. As an example, in model 5, a 0.66 GPA point improvement in TSM 1 increases the likelihood of graduation by more than two and a half times. Since the TSM values indicate the difference between the students' transfer GPA and their GPA at the end of their first three post-transfer terms, a smaller TSM value indicates their GPA at the receiving institution is higher.

Model 1 included only the transfer GPA and was found to be a significant contributor to the model. However, the  $R^2$  values were very low indicating this model did not provide an explanation for the differences in graduation rates. In model 2, the transfer student type was added, and both types of lateral transfer students were found to be significant. However, there were minimal improvements to the  $R^2$ , indicating this model is also not a good fit. The third model removed the transfer student type and student demographics were added, including gender, race, and residency. A race of Not Reported was the only significant variable in the student demographics. Improvements were made to the fit of the model as indicated by the  $R^2$  values. Model 4 removed the demographics and added in the three TSM variables, which were all found to be significant. This model also produced a significant improvement to the  $R^2$  values, indicating this model is a relatively good fit. The last model combined all variables and resulted in the best fit with an  $R^2$  of 0.30 and 0.44 for Cox and Snell and Nagelkerke, respectively, and the lowest AIC value (Field, Miles, Field, 2012).

Transfer GPA and the three transfer shock measurements are found to be the most significant variables in the models. The odds ratio for transfer GPA increases with each addition

of variables, and the odds ratios for the transfer shock measurement decreases slightly when additional variables are added in. Gender and residency were not found to be significant predictors, and only the race category of Not Reported was found to be significant. These findings confirm that transfer shock in each of the first three terms is a predictor of graduating in engineering within four years. This is an important finding as we experience growth in the transfer population and consider how to improve their graduation rates.

Given the large standard deviation in the TSM variables, we grouped the TSM values into five levels to attempt to better understand the influence of transfer shock on 4-year graduation rates. The mean and standard deviation of the categories are presented in Table 5.10, and the number and percentage of students in each level are presented in Table 5.11.

Table 5.10 Mean and Standard Deviation of Transfer Shock Categories by Level

<b>Level</b>	<b>Shock Measurement</b>	<b>TSM 1 Mean (Std. Dev.)</b>	<b>TSM 2 Mean (Std. Dev.)</b>	<b>TSM 3 Mean (Std. Dev.)</b>
1	0 or higher	0.28 (0.28)	0.27 (0.26)	0.31 (0.30)
2	-(0.1 – 0.49)	-0.25 (0.14)	-0.25 (0.14)	-0.24 (0.14)
3	-(0.5 – 0.74)	-0.61 (0.07)	-0.62 (0.07)	-0.61 (0.07)
4	-(0.75 – 1.24)	-0.96 (0.14)	-0.96 (0.15)	-0.97 (0.14)
5	-1.25 or below	-1.78 (0.53)	-1.80 (0.51)	-1.79 (0.51)

Table 5.11 Number and Percent of Students in Each Level

<b>Category</b>	<b>Shock Measurement</b>	<b>TSM 1</b>	<b>TSM 2</b>	<b>TSM 3</b>
1	0 or higher	165 (21%)	160 (20%)	177 (22%)
2	-(0.1 – 0.49)	229 (29%)	228 (29%)	236 (30%)
3	-(0.5 – 0.74)	115 (15%)	115 (15%)	120 (15%)
4	-(0.75 – 1.24)	150 (19%)	171 (22%)	147 (19%)
5	-1.25 or below	90 (11%)	115 (15%)	109 (14%)

The five levels were determined using the average transfer GPA and sampling different ranges of TSM values to determine those with a similar distribution, considered meaningful to academic standing, and that provided an ease of use for practitioners. These categories also significantly reduced the standard deviation. Each category represents the transfer shock value, which is the transfer GPA minus the term GPA at the receiving institution. The categories follow a step-based classification. Level 1 is based on a student having no change or a positive change in their GPA. Level 2 begins with a negative change and continues through just under a half of a GPA point. Since the average GPA of this population was a 3.5, the average student in this category would have a 3.0 term GPA, which is a marker GPA at this institution. For level 3, the range is from a half of a GPA point to just under three-quarters of a GPA point decrease. Using a quarter of a GPA point range in this category provided similarity in the category sizes. Level 4 has a half of a GPA point range, beginning with three-quarters of a GPA point through just under one and a quarter GPA points. This also provided a similar category size. Lastly, level 5 includes any student with a 1.25 GPA point decrease or more.

Table 5.12 demonstrates the graduation rates of students based on the lowest level a student reaches in their first three post-transfer terms. The highest level is level 1 which has a zero or positive change in GPA compared to the transfer GPA. The lowest level is level 5 which has a decrease of 1.25 points or more in the post-transfer term GPA compared to the transfer GPA.

Table 5.12 Graduation Rates by Highest Level Category

<b>Highest Level</b>	<b>4-Year Graduation Rate</b>	<b>Did not Graduate in Engineering within 4 Years</b>
1	-- (96%)	-- (4%)
2	-- (94%)	-- (6%)
3	109 (87%)	17 (13%)
4	190 (80%)	48 (20%)
5	103 (48%)	113 (52%)

The raw numbers cannot be provided for those whose lowest category in the first three post-transfer terms was Level 1 or Level 2 due to small numbers not graduating. Collectively, there were 209 students in those two levels, and they had a 4-year graduation rate over 90%. As the students transfer shock measurement increases, and their level decreases, they will have lower 4-year graduation rates. These findings demonstrate the importance of monitoring student progress past the first post-transfer term and developing methods to decrease students' transfer shock.

### 5.6.3 Limitations

This study has two main limitations. First, it is focused on a single institution which limits the generalizability of the results to other institutions. Specifically, this institution is a land-grant institution with a top-ranked college of engineering. Second, the dataset was missing complete data for 444 of the students admitted as engineering transfer students from 2009 through 2014; subsequently, those students were removed from the data analysis. Those 444 students provide a different mix of engineering transfer student sub-groups than those used in the analysis. A higher percentage of lateral in-state students were in the data analyzed and vertical transfer students with no associate degree had a lower percentage in the dataset than those excluded. The other two categories are very similar in their numbers. The majority of the missing data was in the earlier

years, indicating this data is being requested and documented with more regularity which can improve future studies.

## 5.7 Discussion

Previous research on transfer students has focused mainly on vertical transfers (Tobolowsky & Cox, 2012). A growing number of transfer students are entering as lateral transfers (Shapiro et al., 2017), which creates a need to also focus research efforts on lateral transfer students. Lakin and Cardenas Elliott (2016) found vertical engineering transfer students experience higher levels of transfer shock than vertical engineering transfer students. However, we are unaware of any research that disaggregates the engineering transfer student population into the four distinct sub-groups as has been done in this work (i.e., vertical transfer students with no associate degree, vertical transfer students with an associate degree, lateral in-state transfer students, and lateral out-of-state transfer students). Further, previous research has found transfer shock to be an impactful event for transfer students (Anderson-Rowland, 2011; Hutton & Panter, 2015; Lakin & Cardenas Elliott, 2016; Mattis & Sislin, 2005). However, this concept is most often identified as occurring in the first post-transfer term. In this work, we have conducted an analysis of transfer shock in the first, second, and third post-transfer terms. The results suggest institutions should further examine the transition experiences of their engineering transfer students, determine the types of engineering transfer students attending their institution, and be aware of how each sub-group may have different transitioning experiences, which is a predictor of their ability to graduate from engineering within four years.

### 5.7.1 Transfer Adjustment

The term transfer shock was coined in 1965 to describe a transfer student's temporary drop in GPA during their first-term of enrollment at the receiving institution (Hills, 1965). However, the findings from this study suggest that this drop is not temporary. The first post-transfer term has the least net change in GPA, and the highest net GPA change is in the second post-transfer term. The third post-transfer term shows some improvement compared to the second post-transfer term, but is still a larger net GPA change than the first post-transfer term. Based on these findings, it is appropriate to consider this phenomenon as a transfer adjustment that takes place for each student, rather than a singular transfer shock. Transfer adjustment refers to a more permanent norm for each student, as opposed to a temporary shift that will return to its previous state.

The transfer adjustment was found to be different across the engineering transfer student sub-groups, most specifically between the lateral transfer students and the vertical transfer students with no associate degree. The lateral transfer students experience the lowest degree of transfer adjustment, with a decrease of 0.3 to 0.5 GPA points, while the vertical transfer students without an associate had a decrease of 0.6 GPA points. Diaz (1992) encouraged institutions to determine how long it takes for students to recover from transfer shock. However, these findings indicate that students may not recover from their level of transfer adjustment.

Experiencing transfer adjustment can lead to a decrease in motivation. Authors (Under Review) demonstrated that motivation was a factor affecting engineering transfer student persistence that is influenced by both the student and institution. It is important for institutions to understand the transfer adjustment ranges of their engineering transfer student population and educate students on this concept. Being transparent with students regarding their transition can provide encouragement that this is normal and can help counter any decreases in motivation.

### 5.7.2 Engineering Transfer Student Sub-Groups

The second main finding is that graduation rates differ significantly between the engineering transfer student sub-groups. This finding aligns with researchers that indicate vertical engineering transfer students with an associate degree have higher persistence rates than those without an associate degree (Darrow & Laanan, 2012; Hutton & Panter, 2015). It also aligns with findings related to residency, which indicate in-state engineering transfer students persist at a higher rate than out-of-state engineering transfer students (Cosentino et al., 2014). In a recent study through the Jack Kent Cooke Foundation, it was found that vertical transfer students graduate at higher rates than lateral transfer students (Glynn, 2019). However, Glynn's findings conflict with the findings in this study, which indicate that lateral engineering transfer students have a higher 4-year graduation rate than vertical engineering transfer students. To improve graduation rates of engineering transfer students, it will be important to understand the differences in graduation rates between the engineering transfer student sub-groups, and develop strategic plans for each.

### 5.7.3 Transfer Adjustment Affects Graduation

The third main finding is that transfer GPA and the three transfer shock measurements, or transfer adjustment, are significant predictors of 4-year graduation rates. Transfer GPA was cited by multiple researchers as predictor of student persistence, with a higher transfer GPA leading to a higher persistence rate (Ivins, Copenhaver, & Kocklanes, 2017; Lakin & Cardenas Elliott, 2016; Lopez & Laanan, 2012). Additionally, a higher first post-transfer semester GPA was cited by researchers as a predictor of increased persistence rates (Anderson-Rowland, 2011; Laugerman, Rover, Shelley, & Mickelson, 2015). The transfer GPA and the first post-transfer term GPA were

used to determine the first post-transfer term transfer shock measurement in our study. However, this research expanded beyond the first post-transfer term and also used the second and third post-transfer term GPAs to operationalize two additional transfer shock measurements, resulting in the introduction of transfer adjustment as a more appropriate descriptor of this transition. As institutions and researchers seek to improve graduation rates in engineering transfer students, they should not limit their efforts to the student's first post-transfer term. Rather, they should develop longitudinal support programs designed for the specific engineering transfer student sub-groups, in addition to being transparent regarding the level of transfer adjustment engineering transfer students should expect at that institution.

#### 5.7.4 Transfer Adjustment Scale

The last main finding was the development of a transfer adjustment scale that provides insight into how the varying levels of transfer adjustment can impact graduation. Students that experience less than 0.5 points of a decline in GPA across the first three post-transfer terms have the highest graduation rates. Those that experience a decrease of 1.25 GPA points or more during any of their first three post-transfer terms have the lowest graduation rates. While transfer adjustment may be inevitable, limiting the level of adjustment should be a focus for institutions and researchers. A better understanding of high impact practices that can improve transfer adjustment is needed.

Several directions for future research were identified through this analysis. First, findings suggest that institutions should develop a multi-phase transition program. Each of the first three post-transfer terms should include a set of transition programs designed to address each of the

engineering transfer student sub-groups and the obstacles they face in each of those terms. Second, additional analysis of VNAD students is needed to better understand their post-transfer transition compared to the other student sub-groups. Providing a more successful initial transition could then provide the foundation for a better second and third post-transfer terms. Third, further analysis should be completed to determine how to influence the level of transfer adjustment that students experience.

The results of this study emphasize the importance of institutions understanding that engineering transfer students are not a homogeneous population and that students experience a transfer adjustment phase. There are key differences between lateral and vertical transfer students. Differences were also identified between the types of lateral transfer students, as well as between the types of vertical transfer students. These findings and recommendations can be useful to the engineering education community as they seek to graduate more engineers, as well as enrollment management offices which seek to improve persistence rates at their institutions (Hossler & Bontrager, 2015).

## 5.8 Conclusion

As a greater number of students are pursuing transfer pathways (Glynn, 2019), engineering transfer students provide an important method of meeting the nation's goal of graduating more engineering students. The purpose of this study was to ascertain key differences when this population is disaggregated into four distinct sub-groups, capturing the type of institution students transfer from (i.e., lateral vs. vertical and in-state vs. out-of-state) and if they obtained an associate degree when transferring from a 2-year institution. Additionally, this study focused on reviewing transfer shock and 4-year graduation rates for each of these engineering transfer student sub-groups. The study

resulted in expanding the idea of transfer shock beyond an occurrence solely in the first post-transfer term, but rather consider it as a transfer adjustment that extends beyond the first post-transfer term. This study also demonstrates the engineering transfer student sub-groups experience different levels of transfer adjustment, which is a predictor of their 4-year graduation rates.

For practitioners, this study suggests that more strategic programming and decision-making should be considered by institutions to provide a more focused method for increasing persistence of their engineering transfer students. For the engineering education and enrollment management communities, this study provides a more granular understanding of engineering transfer students and suggests the key differences among this population that should be considered in future research. The findings from this research are based on a single-institution dataset, however, the results are generalizable for other large public research institutions with similar types of engineering transfer student sub-groups.

## 5.9 Acknowledgements

This material is based on work supported by the National Science Foundation Grant No. 1712089. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

## References

- Alting, A., Delale, F., & Barba, J. (2013). Bridges to engineering: success for transfers. *2013 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Atlanta, GA.
- American Society for Engineering Education (ASEE). (2017). *Engineering By The Numbers*. Washington, D. C.

- Anderson, M., Perez, L., Jones, D., Zafft, C. (2011). Success factors for students transferring into undergraduate engineering degree programs. *2011 Frontiers in Education Conference (FIE) Proceedings*. Rapid City, SD.
- Anderson-Rowland, M. (2000). Understanding engineering students for better recruitment strategies: A four-year study. *2000 Frontiers in Education (FIE) Conference Proceedings*. Kansas City, MO.
- Anderson-Rowland, M. (2009). An academic scholarship program for transfer students in engineering and computer science: a five-year summary. *2009 American Society for Engineering Education (ASEE) Conference Proceedings*. Austin, TX.
- Anderson-Rowland, M. (2011). Reducing GPA shock for engineering and computer science community college transfer students. *2011 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Vancouver, B.C., Canada.
- Anderson-Rowland, M. (2013). Expectations and realities for community college engineering transfers at a large university. *2013 IEEE Frontiers in Education (FIE) Conference*. Oklahoma City, OK.
- Auerbach, J. & Williams, D. (2013). The ties program: a transfer initiative for engineering students. *2013 IEEE Frontiers in Education (FIE) Conference*. Oklahoma City, OK.
- Authors. (Under Review). *Journal of Engineering Education*.
- Bohanna, D. & Ebbers, L. (2016). Academic and social experiences of female community college transfer students in engineering fields at midwestern university. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.

- Brawner, C. & Mobley, C. (2016). Advising matters: engineering transfer students' transition experiences at five institutions. *International Journal of Engineering Education*. Vol. 32, No. 6, pp. 2446-2459.
- Carlan, P. & Byxbe, F. (2000). Community colleges under the microscope: an analysis of performance predictors for native and transfer students. *Community College Review*. Vol. 28, No. 2, pp. 77-93.
- Cejda, B., Kaylor, A., Rewey, K. (1998). Transfer shock in an academic discipline: The relationship between students' major and their academic performance. *Community College Review*. Vol. 26, No. 3, pp. 1-13.
- Cotts, E., Fang, J., Jones, W., Klotzkin, D., Myers, G., & White, B. (2016). A STEM program focused on transfer student success at Binghamton University. *2016 IEEE Frontiers in Education (FIE) Conference Proceedings*. Eerie, PN.
- Coyote, R. (2013). The relevance of career aspirations for transfer students persisting in science, technology, engineering and math disciplines. (Doctoral Dissertation). University of Arizona.
- Darrow, M. & Laanan, F. (2012). Engineering transfer student leavers: voices from the sidelines of the engineering playing field. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- Fayer, S., Lacey, A., & Watson, A. (2017). STEM occupations: past, present, and future. Spotlight on Statistics. *U.S. Bureau of Labor Statistics Spotlight on Statistics*. Retrieved February 2019 from <https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf>

- Field, A., Miles, J., Field, Z. (2012). *Discovering Statistics Using R*. SAGE Publications. Thousand Oaks, CA.
- Freedman, D. (2005). *Statistical Model: Theory and Practice*. Cambridge University Press. Cambridge, MA.
- Glass, J., & Harrington, A. (2002). Academic performance of community college transfer students and “native” students at a large state university. *Community College Journal of Research and Practice*, 26, 415-430. doi: 10.1080/0277677029141774.
- Glynn, J. (2019). Persistence: The Success of Students Who Transfer from Community Colleges to Selective Four-Year Institutions. Lansdowne, VA: Jack Kent Cooke Foundation.
- Graham, S. & Dallam, J. (1986). Academic probation as a measure of performance: contrasting transfer students to native students. *Community/Junior College Quarterly of Research and Practice*. 10. 23-24.
- Habley, W., Bloom, J., & Robbins, S. (2012). *Increasing Persistence: Research-Based Strategies for College Student Success*. San Francisco, CA: Jossey-Bass.
- Hennessey, N. (2019). Overcoming shock: An examination of transfer shock and student resiliency. (Master’s Thesis). Retrieved from the University of Arizona Campus Repository.
- Hills, J. (1965) Transfer shock: The academic performance of the transfer student. *The Journal of Experimental Education*, Vol. 33, No. 3.
- Holahan, C., Green, J., & Kelley, P. (1983). A 6-year longitudinal analysis of transfer student performance and retention. *Journal of College Student Personnel*. Vol. 24, Issue 4.
- Hossler, D. & Bontrager, B. (2015). *Handbook of Strategic Enrollment Management*. San Francisco: Jossey-Bass an Imprint of Wiley.

- Hutton, R. & Panter, A. (2015). Modeling bachelor's degree completion rates of North Carolina community college transfer students using a discrete-time survival analysis. (Doctoral Dissertation). Retrieved from the University of North Carolina.
- Ishitani, T. (2008). How do transfers survive after “transfer shock”? A longitudinal study of transfer student departure at a four-year institution. *Research in Higher Education*, 49, 403-419.
- Ivins, T., Copenhaver, K., & Koclanes, A. (2017). Adult transitional theory and transfer shock in higher education: practices from literature. *Reference Services Review*. Vol. 45, Issue 2, pp. 244-257. doi.org/10.1108/RSR-08-2016-0048
- Jackson, D. & Laanan, F. (2015). Desiring to fit: fostering success of community college transfer students in STEM. *Community College Journal of Research and Practice*. Vol. 39, No. 5, pp. 132-149.
- Jones, S. & Waggenspack, W. (2015). BRCC to LSU engineering pathway to success. *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- Laier, J. & Steadman, S. (2014). Improving transfer student success. *2014 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Indianapolis, IN.
- Lakin, J. & Cardenas Elliott, D. (2016). STEMing the shock: examining transfer shock and its impact on stem major and enrollment persistence. *Journal of the First-Year Experience & Students in Transition*. Vol. 28. No. 2.
- Laugerman, M. & Shelley, M. (2013). A structural equation model correlating success in engineering with academic variables for community college transfer students. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.

- Laugerman, M., Shelley, M., Rover, D., & Mickelson, S. (2015). Estimating survival rates in engineering for community college transfer students using grades in calculus and physics. *International Journal of Education in Mathematics, Science and Technology*. Vol. 3. No. 4. pp. 313-321.
- Lopez, C. & Laanan, F. (2012). Transfer students in STEM majors at a midwestern university: academic and social involvement factors that influence student success. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- McBurnie, J., Campbell, M., & West, J. (2012). Avoiding the second year slump: A transition framework for students progressing through university. *International Journal of Innovation in Science and Mathematics Education*. Vol. 20. No. 2.
- Mattis, M. & Sislin, J. (2005). *Enhancing the community college pathway to engineering careers*. National Academies Press. Washington, DC.
- Mattis, L., Lancey, P. Nair, U., Straney, R., Georgiopoulos, M., & Young, C. (2012). Engineering and Computer Science Community College Transfers and Native Freshmen Students: Relationships Among Participation in Extra-Curricular and Co-Curricular Activities, Connecting to the University Campus, and Academic Success. *2012 American Society for Engineering Education (ASEE) Conference Proceedings*. San Antonio, TX.
- McHugh, M. (2013). The chi-square test of independence. *Biochemia medica*. Vol. 23, No. 2, pp. 143-149.
- Mobley, C. & Brawner, C. (2013). Engineering transfer students' views on orientation and advising. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.

- Mohd Razali, N. & Wah, Y. (2011). Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *Journal of Statistical Modeling and Analytics*. Vol. 2, No. 1, pp. 21-33.
- Ohland, M., Camacho, M. Layton, R. Lord, S., & Wasburn, M. (2009). How we measure success makes a difference: Eight-semester persistence and graduation rates for female and male engineering students. *2009 American Society for Engineering Education (ASEE) Conference Proceedings*. Austin, TX.
- President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Author.
- Sarder, B. (2013). Bridging the gap in transition of students from community colleges to universities. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.
- Scott, T., Thigpin, S., & Bentz, A. (2017). Transfer learning community: overcoming transfer shock and increasing retention of mathematics and science majors. *Journal of College Student Retention: Research, Theory & Practice*. Vol. 19. No. 3. pp. 300-316.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Yuan, X., Nathan, A. & Hwang, Y. (2017). Tracking Transfer: Measures of Effectiveness in Helping Community College Students to Complete Bachelor's Degrees (Signature Report No. 13). *National Student Clearinghouse Research Center*.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Bhimdiwali, A., Nathan, A., & Youngsik, H. (2018). Transfer and Mobility: A National View of Student Movement in Postsecondary

- Institutions, Fall 2011 Cohort (Signature Report No. 15). Herndon, VA: National Student Clearinghouse Research Center.
- Shields, N. & Pietroburgo, J. (2000). Comparing the success of two-year college students and students with other academic backgrounds in a non-traditional engineering program. *2000 American Society for Engineering Education (ASEE) Conference Proceedings*. St. Louis, MO.
- Sullivan, M., de Cohen, C., Barna, M., Orr, M., Long, R., & Ohland, M. (2012). Understanding engineering transfer students: demographic characteristics and educational outcomes. *2012 IEEE Frontiers in Education (FIE) Conference Proceedings*. Seattle, WA.
- Tabachnick, B. & Fidell, L. (2013). *Using Multivariate Statistics* (6<sup>th</sup> ed). Boston, MA: Pearson.
- Tkacik, P., Lim, J., Tolley, P., & Warren, K. (2012). Gendered socialization during the first semester: contrasting experiences of male and female transfer/non-traditional engineering students. *2012 American Society for Engineering Education (ASEE) Conference Proceedings*. San Antonio, TX.
- Tobolowsky, B. & Cox, B. (2012). Rationalizing neglect: an institutional response to transfer students. *The Journal of Higher Education*. Vol. 83, No. 3, pp. 389-410.
- Western Interstate Commission for Higher Education (WICHE). (2017). *Knocking at the College Door: Projections of High School Graduates*. Retrieved February 2019 from <https://static1.squarespace.com/static/57f269e19de4bb8a69b470ae/t/58d2eb93bf629a4a3878ef3e/1490217882794/Knocking2016FINALFORWEB-revised021717.pdf>
- Wilder, J. (1993). A sophomore slump: A complex developmental period that contributes to attrition. *College Student Affairs Journal*. Vol. 12, No. 2, pp. 18-27.

Zapf, M. (1991). Cross-cultural transitions and wellness: dealing with culture shock.

*International Journal for the Advancement of Counseling*. Vol 14, No. 2, pp. 105-119.

## Chapter 6

### System Dynamics Model Development and Testing

(Manuscript 4: Developing a Simulation Model to Examine Persistence of Engineering Transfer Students)

#### 6.1 Abstract

The demand for engineering graduates in the United States continues to grow, yet the number of students entering post-secondary education is declining and graduation rates have seen little to no change over the last several decades. Engineering transfer students are a growing population and can help meet the nation's needs, however, there is little research on the persistence of this population after they transfer to the receiving institution. A large public southeastern research university is expecting a continued increase in their engineering transfer students and wishes to focus more on the retention and graduation of these students. Understanding student persistence requires a systems approach that considers a wide range of factors and considers changes and delays in the system over time. In this paper, a system dynamics simulation model was created to demonstrate the throughput of the students in a four-year timespan and identify key leaving patterns, as well as opportunities to affect those leaving patterns. We simulate the model and test the fidelity of the model by endogenously generating different cohort data. The model showed students are leaving in the second post-transfer year, and the leaving rates have been changing over time. Additionally, the graduation rates in the third post-transfer year have high variability. The model provided insight into why the variability occurs and how the institution can control it through institution-influenced behaviors. Overall, the study suggests a new approach for understanding student persistence and how institutions can affect change.

## 6.2 Background

Increasing the number of engineering graduates continues to be a national priority after a report from the President's Council of Advisors on Science and Technology (PCAST, 2012). This growth is necessitated by a need for engineering professionals to step into the 500,000 new jobs that will be added over the next 10 years, as well as positions that will be vacated (Fayer, Lacey, & Watson, 2017). While efforts to enroll more engineering students have been implemented to meet this challenge, there has also been a focus on improving retention and graduation rates, commonly referred to as persistence. However, in the last several years, the graduation rates in engineering have only increased by approximately one percent (ASEE, 2017).

Much of the engineering persistence literature focuses on the persistence of first-time, full-time students (Brawner & Mobley, 2016; Mobley, Brawner, & Long, 2014; Sullivan de Cohen, Barna, Orr, Long, & Ohland, 2012; Tobolowsky & Cox, 2012). Transfer students are defined as those attending more than one institution on their route to a bachelor's degree, and represent a growing trend in the U.S. (Habley, Bloom, & Robbins, 2012; Brawner & Mobley, 2016). Reports from the National Student Clearinghouse (NSC) confirm this trend with recent reports indicating that 21% of students who began at a 4-year institution chose to transfer to another 4-year institution and 22% of students who began at a 2-year institution chose to transfer to a 4-year institution (Shapiro, Dundar, Huie, Wakhungu, Bhimdiwali, Nathan, & Youngsik, 2018). This is an increase from the 2012 NSC report, which indicated 17% and 20%, respectively (Hossler, Shapiro, Dundar, Ziskin, Chen, Zerquera, & Torres, 2012).

Understanding this population of students and how to improve their persistence within engineering can provide additional pathways to meet the need for engineering graduates. However, the existing literature on engineering transfer students is largely focused on creating effective

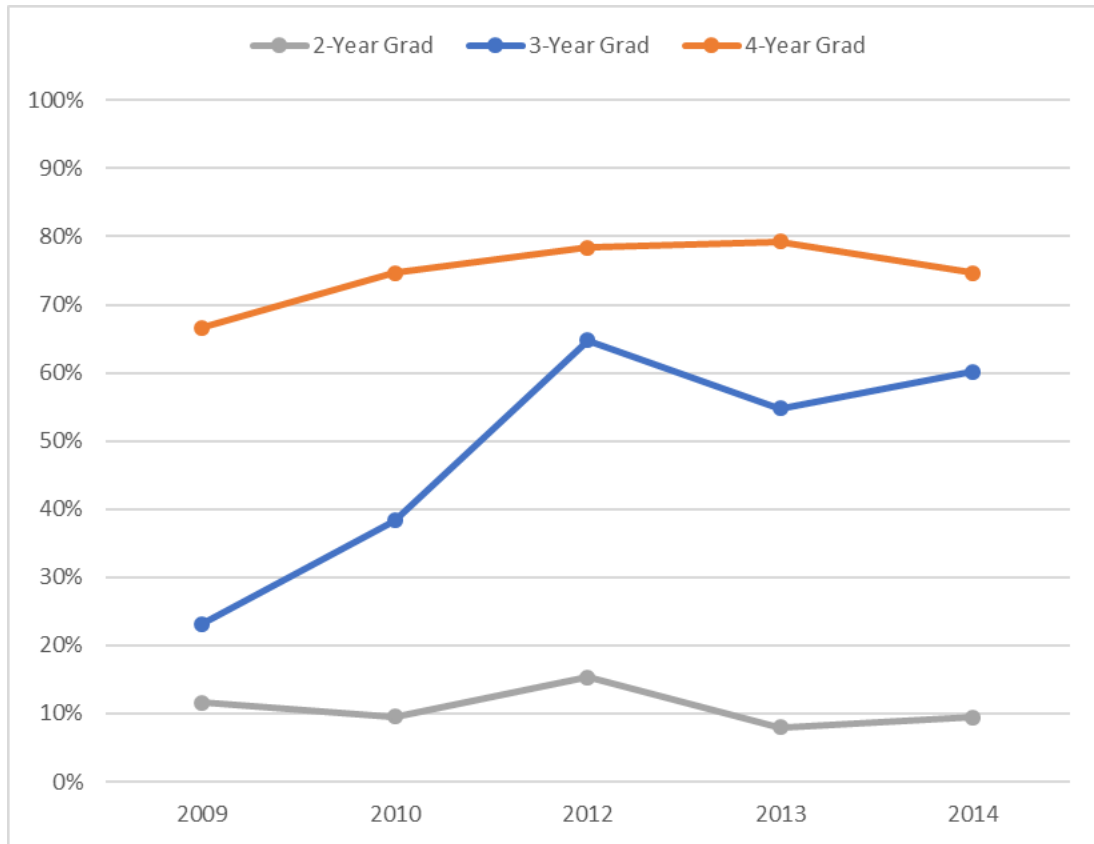
pathways for transferring, specifically from in-state community colleges (Authors, Under Review). Researchers have only recently begun looking at post-transfer experiences of engineering transfer students and attempting to understand how to improve their graduation rates. A limitation in the current literature is a narrow focus on the post-transfer experience during the first term of enrollment. Authors (Under Review) suggest expanding the system boundary to study persistence over time. This work is a first step in response to this gap.

### 6.3 Research Objectives and Approach

This research is based on an institutional focus on transfer students at a large public southeastern research university (Institution Alpha). Engineering represents approximately 30% of the total enrollment at Institution Alpha, and engineering transfer students account for 14% of the total engineering student population. Institution Alpha has indicated it will continue to grow admissions for transfer students. As the number of transfer students continue to increase, the college of engineering at Institution Alpha is placing a larger focus on these students. Figure 6.1 provides the 2-year, 3-year, and 4-year graduation rates for engineering transfer students who began in 2009 through 2014.

Often transfers arrive to their receiving institution expecting to graduate in two years, but only 17% of transfer students will earn a bachelor's degree within six years (Aspen Institute, Community College Research Center, Public Agenda, & Sova Solutions, 2017). The statistics are much better at the institution in this study, however, as shown in Figure 6.1, there is a large amount of variation in the 3-year graduation rates. Understanding the reasons for this variation can help the institution know what changes may have caused this behavior.

Figure 6.1 Engineering Transfer Student Graduation Rates at Institution Alpha



Regression models are most often used to understand significant predictors of graduation. Several studies also use structural equation modeling to account for the many factors linked to student persistence (French, Immekus, Oakes, 2003; Laugerman & Shelley, 2013; Sass, Castro-Villarreal, Wilkerson, Guerra, & Sullivan, 2018). Event-history analysis has also been used to allow for changes in factors over time (Ishitani, 2008). However, these models work under the assumption of linearity; the authors did not find any analysis using tools for non-linear systems.

The novelty of the current study is the application of system dynamics (SD), a simulation-based systems approach, to the problem of engineering transfer student persistence. The methodology was developed in the early 1960's by Jay Forrester as a means to work with complex systems with many interacting subsystems (Forrester, 1961; Sterman, 2000). The methodology has

been applied in numerous fields, including business, medicine, and economic behavior (Forrester, 1998). There are several applications of system dynamics modeling in education. The promotion chain for the typical faculty pipeline in U.S. higher education institutions has been modeled using SD (Sterman, 2000; Ghaffarzadegan and Xu, 2018). Ghaffarzadegan and Larson (2018) demonstrated the power of SD modeling to examine new grant awards in relation to the federal research budget, to depict post-doc duration in the current U.S. science workforce, and to study the PhD population growth. Kennedy (2011) also highlighted SD modeling in higher education with a focus on managerial applications.

Few models have focused on the detailed representation of the pipeline of education. An exception is Andalib's (2019) model of diversity of the U.S. education system, which models the kindergarten through graduate school pipeline of education, and examines the rate of women throughout the pipeline. Despite some SD models developed for enrollment demands (Frances, 2000; Jordan, 1992; Robledo, 2013), none were found that specifically focused on student persistence. Ghaffarzadegan, Larson, and Hawley (2017) invite more system modeling of education systems, highlighting the non-linearity and complexity of this type of system. We follow this line of research. To better understand what has happened over the last decade and determine how the institution can further support engineering transfer students, we recognize that a systems approach is needed. Using an SD approach, this research has two main research objectives. The first objective is to determine key leaving patterns of engineering transfer students during the first four post-transfer years. The second objective is to provide insights to researchers and practitioners for how to affect leaving and graduation rates of this population.

## 6.4 Methods

#### 6.4.1 Model Development

An explanatory system dynamics model was developed with the objective of understanding the progression of engineering transfer students through four years at Institution Alpha. The model was developed using the Ventana Vensim PLE software. The model was developed in different iterations and was calibrated against data using the partial model calibration method (Homer, 2012; Oliva, 2003). In this method, different parts of the structure of the model were tested separately against the data, which helps further verify the model structure and avoid overfitting the model (Oliva, 2003).

#### 6.4.2 Data

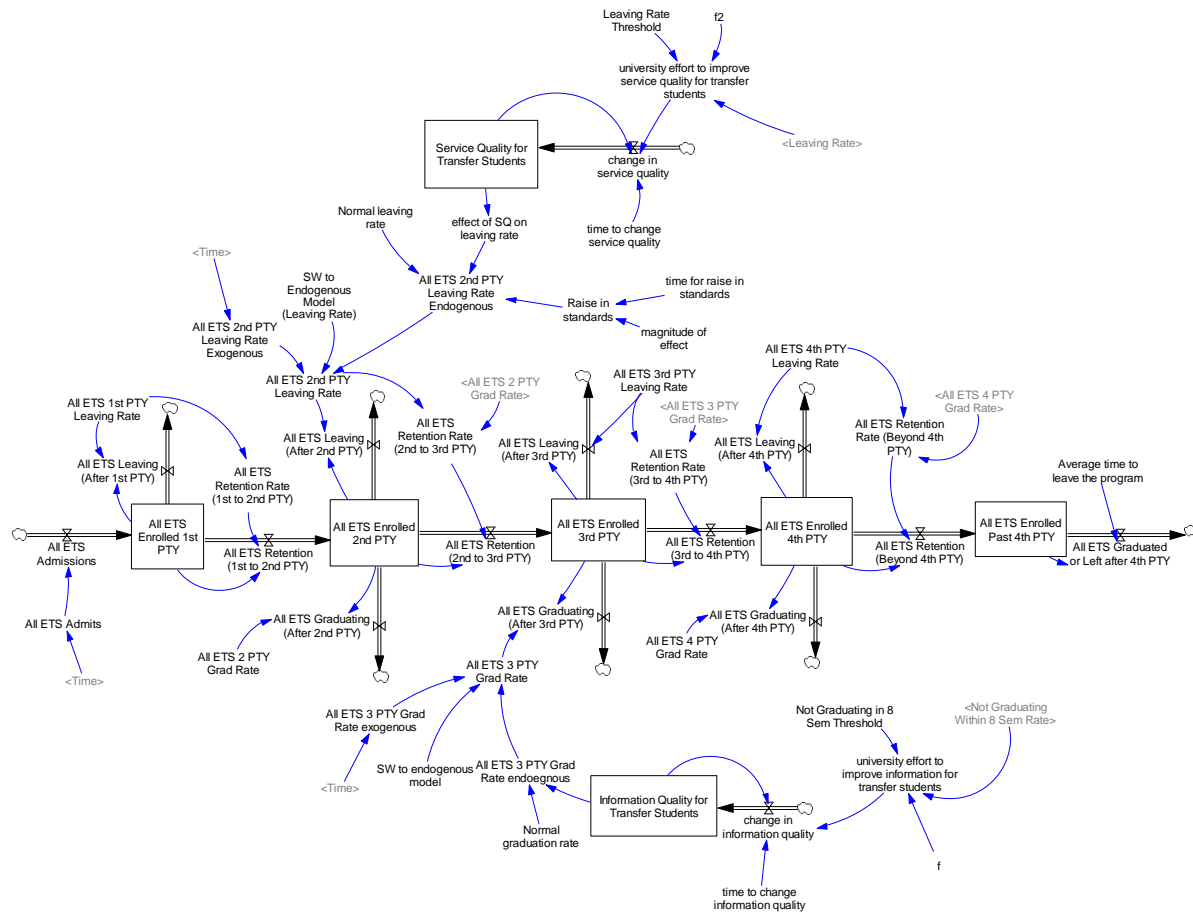
Data on all students enrolled at Institution Alpha from 2009 through 2018 were provided by the University Registrar's Office and the Office of Institutional Research. The institutional enrollment data provided a history of the students' progression through the institution, including their graduation major and date when applicable. From this dataset we were able to determine when students left the engineering program, when they graduated within four years, or if they continued enrollment in engineering past four years. Leaving engineering meant the student changed their major to a non-engineering major, or left the institution. The total dataset included 789 engineering transfer students that began in 2009 through 2014. This provided us with six cohorts to use for model validation. Additionally, one of the authors works in enrollment management at Institution Alpha and has expertise on the throughput of engineering transfer students, which was utilized when creating the model.

### 6.4.3 Model Overview

The core of the model is an aging chain that is initialized with the number of engineering transfer students admitted per year which occurs once per year. This is the only exogenous variable in the model. The students then progress from one year to the next, or they can exit the system through leaving engineering or graduating. Figure 6.2 provides the full aging chain structure for the model. Additional model components were developed to determine the graduation rates for each entering cohort, as well as the leaving rates for each cohort, and the percentage of students that remained enrolled after the fourth year. These components can be viewed in Appendix A.

Enrollment and graduation occur at the beginning and end of academic years. Therefore, the model is formulated as a time-discrete model, which provides a difference-equation model with time periods of one year. While this approach is not common in SD, using smaller time-intervals would unnecessarily complicate the model (Ossimitz & Mrotzek, 2008).

Figure 6.2 Aging Chain Component of SD Model



There are five stock variables within the aging chain. These include the engineering transfer students (ETS) enrolled in the first post-transfer year (PTY), the second PTY, the third PTY, the fourth PTY, and past the fourth PTY. The first stock, “All ETS Enrolled 1<sup>st</sup> PTY”, is based on the number of students admitted each year. Students exit this stock through leaving engineering, or moving into the second PTY. Students can exit the stocks for the second, third, and fourth PTY through leaving engineering, graduating in engineering, or moving into the next year’s stock. In all of these stocks, the number of students exiting equals the number of students in the stock. This results in students not being in the same stock in multiple timesteps; they must

either leave the system or move into the next year's stock. This is slightly different than most SD models where stock variables typically have populations that will remain in the stock during a timestep.

Two balancing feedback loops are present in the system, which influence the graduation and leaving rates of engineering transfer students. Two stock variables are present in these feedback loops, and relate to factors identified as affecting engineering transfer student persistence. The first is service quality which describes the level of service Institution Alpha is providing to the engineering transfer students through their second PTY year. As Institution Alpha increases their level of effort to improve service quality, there is a corresponding decrease effect on the leaving rate in the second PTY. The second stock variable is information quality which describes the types of information Institution Alpha is providing to the engineering transfer student through their third PTY. As Institution Alpha increases their level of effort to improve the types of information available, there is a corresponding increase in the third PTY graduation rates.

The feedback loops are driven by a desired leaving rate during the second year and a desired graduation rate in the third year. An overall leaving rate threshold is linked to the second PTY leaving rate. The difference between the threshold and the actual overall leaving rate drives the service quality provided by the college of engineering as those students transition into the institution, which impacts the leaving rate in the second PTY. The university will adjust their efforts to improve the service quality for the students based on the difference between the threshold and actual leaving rates. Their effort will inflow to the service quality for transfer students. There is a delay of two years from when the college changes their effort and when the impact is recognized in the system. The service quality is a stock variable that accumulates over time,

indicating a constant increase in service quality, but the increase is dependent on the level of effort from the college.

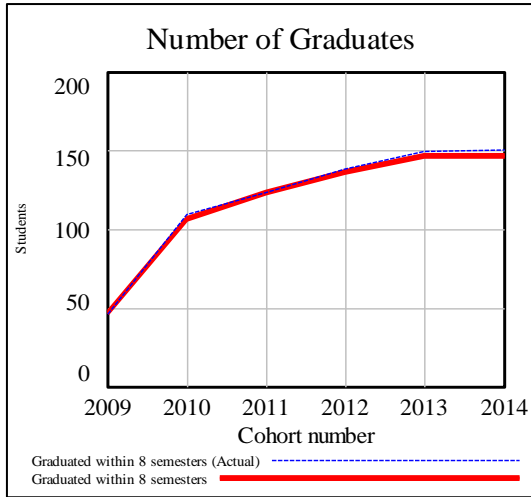
The feedback loop for a desired level of students not graduating in four years is similarly constructed. A threshold for the percentage of students not graduating in four years is linked to the third PTY graduation rate. The difference between the threshold of students not graduating in four years and the simulation percentage of students not graduating in four years drives the change in information quality, which impacts the graduation rate in the third PTY. The university will adjust their efforts to improve the information quality for the students based on the difference between the threshold and actual leaving rates. Their effort will inflow to the service quality for transfer students. There is also a delay of two years from when the college changes their effort and when the impact is recognized in the system. The information quality is a stock variable that accumulates over time, indicating a constant increase in information quality, but the increase is dependent on the level of effort from the college.

The model also includes an adjustment in the second PTY leaving rate in 2014. In this year, the institution implemented new enrollment management policies which increased the number of students leaving. The enrollment management policies placed a GPA restriction on students' ability to declare a specific engineering degree. The restrictions prevented many engineering transfer students from being able to continue pursuit of their intended engineering major, which in turn caused them to leave engineering. To account for this change in the SD model, a variable was introduced that adjusted the leaving rate in 2016 through a STEP function. The variable was labeled as "raise in standards" and an increase in the second PTY leaving rate of 8% was input for 2016 to correspond to two years after the 2014 cohort entered the system.

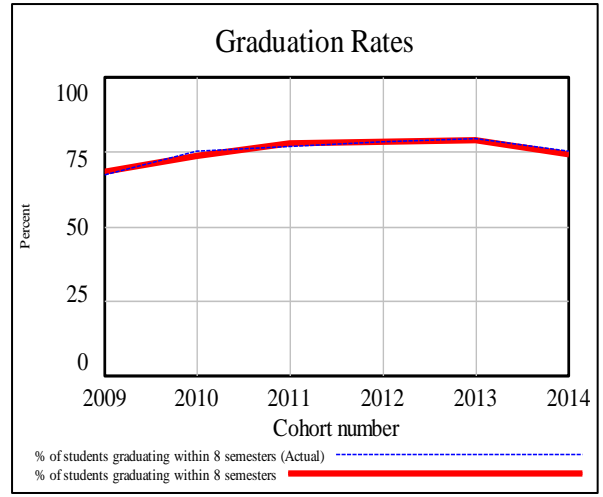
### 6.4.3 Model Testing

A model's purpose is to characterize a system and provide insight into ways to alter the system (Sterman, 2000). While a model is never complete, or completely accurate, there are a variety of tests that can be conducted throughout the model development to improve the model and uncover any issues (Sterman, 2000). As this model was developed, multiple assessment tests were used for validation. First, dimensional consistency was checked using the "Unit Check" tool in Vensim. This test ensured the units of measure were consistent throughout the model. Second, a dataset from Institution Alpha was used to calibrate the SD model. The only exogenous input to our model is admission rate. This dataset was input into Vensim to be used as a baseline by which to measure the accuracy of the model. Figure 6.3 presents the comparisons of several variables in the model compared to actual historical data. The dotted lines represent the historical data and the solid lines represent the simulation. It is important to note that in Figures 6.3a, 6.3b, 6.3c, and 6.3d, the x-axis represents cohorts rather than time. This aligns with the education system which typically reports cohort data.

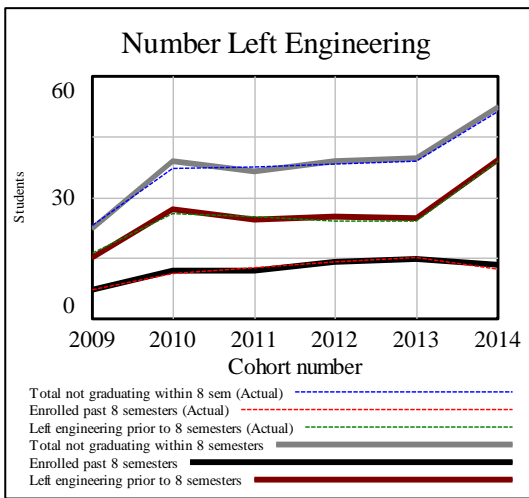
Figure 6.3 Historical and Simulation Results. Note: x-axis in figures a-d is cohort.



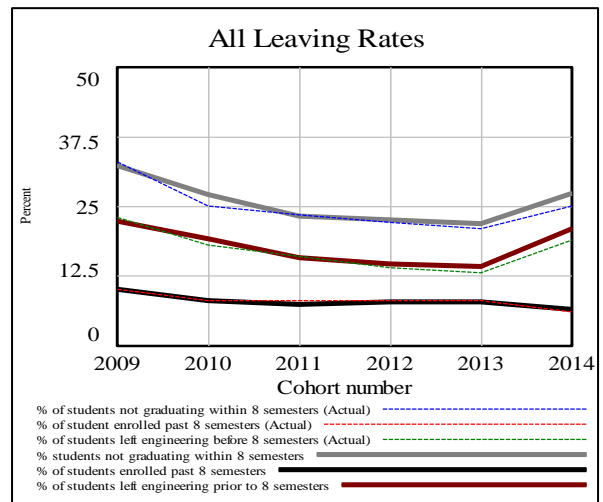
(a)



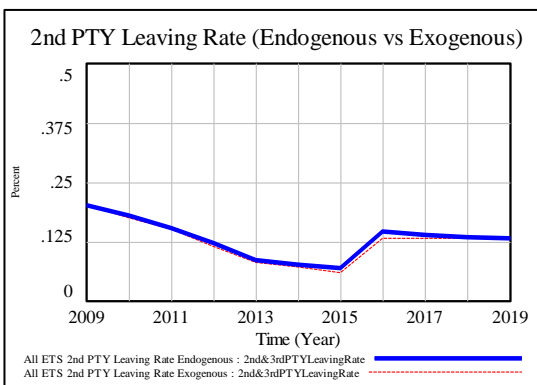
(b)



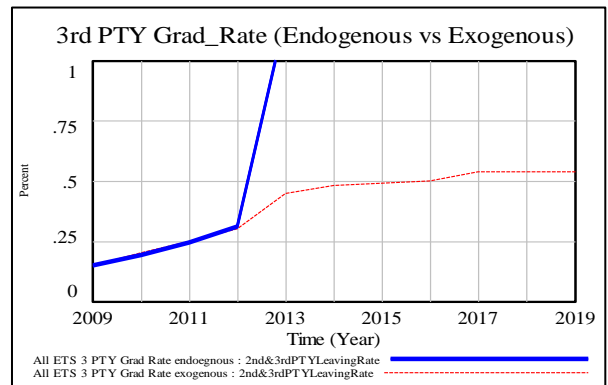
(c)



(d)



(e)



(f)

Table 6.1 also provides the mean absolute percentage error (MAPE) for the actual and simulated number of graduates, number of students leaving, and number of students enrolling past eight semesters. All values are less than 10% which indicates highly accurate forecasting (Lewis, 1982).

Table 6.1 MAPE Values (Number of Graduates, Students Leaving, and Continuing Enrollment)

<b>Variable</b>	<b>MAPE</b>
Number of Graduates within 8 Semesters	0.9%
Number Leaving Engineering	3.7%
Number Continuing Enrollment Past 8 Semesters	3.5%

Lastly, extreme condition tests were completed using values of zero and 100% in two key variables, second PTY leaving rate and third PTY graduation rate. The model outcomes were what would be expected for those types of values.

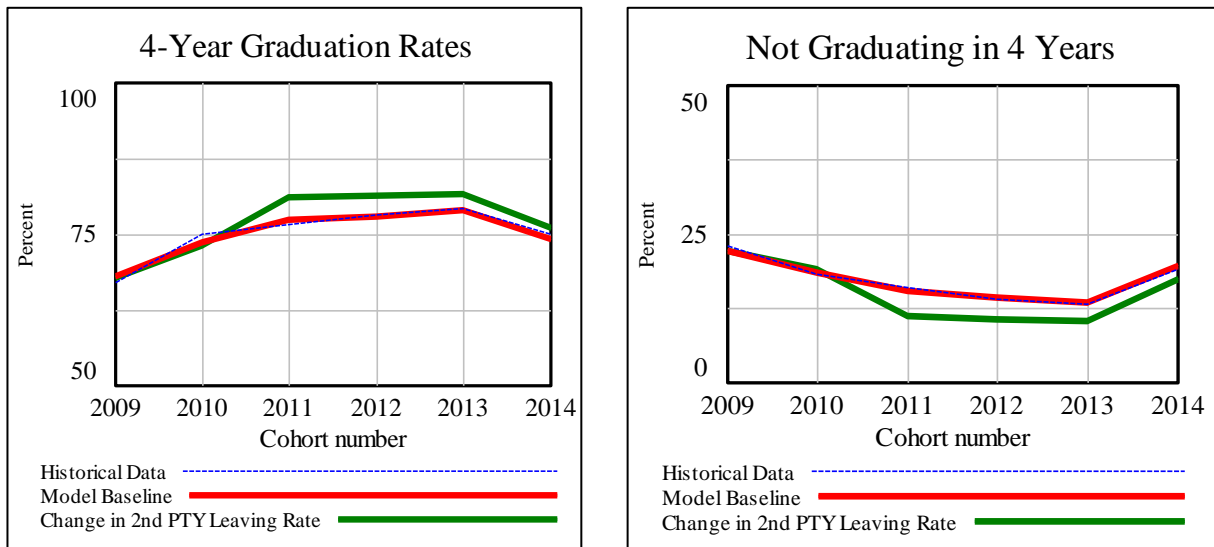
## 6.5 Results and Discussion

The first objective of this research was to determine key leaving patterns of engineering transfer students during the first four PTYs. This objective follows the recommendations from Authors (Under Review) who recommended institutions look beyond the first PTY to better understand this population. The SD model demonstrated two key leaving patterns. The first involves students leaving engineering prior to graduation. The literature focuses on students leaving within the first PTY (Glass & Harrington, 2002; Ishitani, 2008). However, our findings indicate this is not the largest exit point for students leaving engineering. Rather, the leaving rate in the second PTY is much higher and has more variation, ranging from 8% to 20%, than those leaving in any other PTY. This finding further supports the idea of extending the review of engineering students' post-transfer success beyond their first PTY. The second key leaving pattern

occurs when students graduate in the third PTY. The graduation rate in the third PTY ranges from 15% to 48%. The overall 4-year graduation rate has increased by approximately 10% in the same timeframe, which indicates more students are graduating within four years, with an increased percentage finishing in three years.

The model was tested using a change in the leaving rate in the second PTY to determine how it would affect the total percentage of students leaving prior to four years, as well as the 4-year graduation rates. The leaving rate was set to eight percent in 2013, Figure 6.4 shows the effect on these two variables with that change.

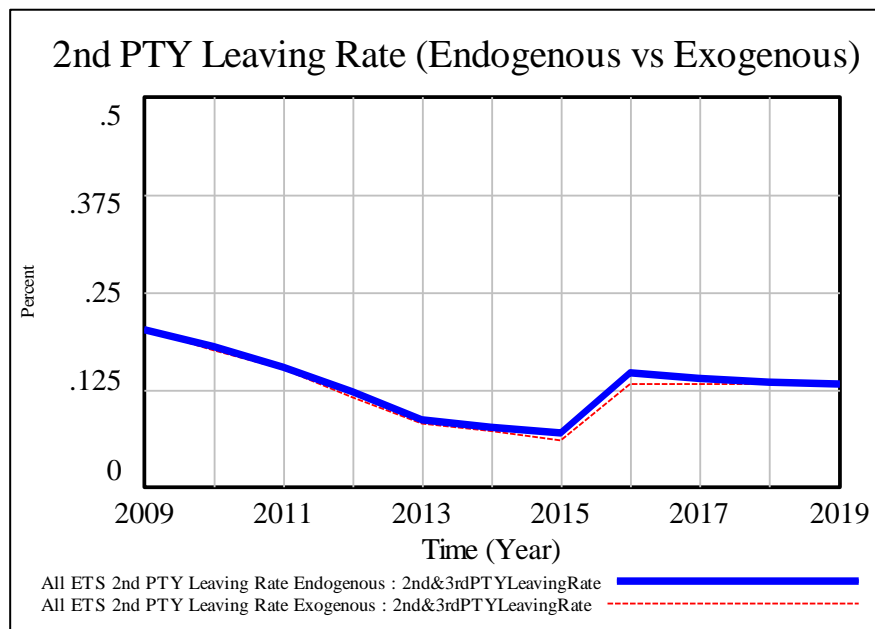
Figure 6.4 Effect of Changing the Leaving Rate in the Second PTY



This change was made in 2013 which affected the 2011 entering cohort of students, and results in higher graduation rates and a lower percentage of students not graduating within four year. The 4-year graduation rate changed from 76% to 81% and the percentage of students leaving before four years decreased from 16% to 11%.

The second objective was to provide insights to researchers and practitioners for how to affect leaving and graduation rates of this population. As we look at the two key leaving patterns, we can discern drivers that influenced these rates over time. The first leaving pattern identified is the rate of students leaving in the second PTY. The SD model demonstrated a service quality component that affected change within this variable. Figure 6.5 provides the change in the second PTY leaving rates over time. It is important to note for this graph the years are not cohort years. The students that entered in 2009 are represented in 2011 and so forth.

Figure 6.5 Leaving Rate in the Second Post-Transfer Year at Institution Alpha



Through 2015 there is a gradual decline in the leaving rate. This represents cohorts admitted from 2009 through 2013. The goal-seeking feedback loop linked to service quality provides an explanation for this gradual decrease. An overall leaving rate threshold was set to 22%, and this was compared to the simulated leaving rate. Based on differences between these values, the university exerts more or less effort to their service quality for engineering transfer students.

As the effort increases, the service quality increases. However, there is a delay between when the institution implements a change and when the change affects the system. The time to change for this component is two years. This provides a gradual decrease of the leaving rates. However, in 2016, which is the 2014 entering cohort, there is a sharp increase in the leaving rate during the second PTY. After some analysis, it was determined that a new enrollment policy was put into place during that year which had an adverse effect on students leaving. Adjustments were made through service quality and the leaving rate is again gradually declining.

Service quality encompasses several of the factors identified as affecting engineering transfer student persistence. Figure 6.6 provides an overview of the complete set of factors, which are classified in seven categories (Authors, Under Review).

Figure 6.6 Categories and Factors Identified from the Literature (Authors, Under Review)

<p><b>Student Characteristics <sup>1</sup></b></p> <p>Scholarship recipient (24%)</p> <p>Demographics (16%) (gender, race, ethnicity, age)</p> <p>Parental Education (6%)</p> <p>Financial need (2%)</p> <p>Residency (1%)</p>	<p><b>Pre-Transfer Academics <sup>1</sup></b></p> <p>Number of credits completed (13%)</p> <p>Overall GPA (10%)</p> <p>Completion of associate degree (9%)</p> <p>Core engineering courses completed (7%)</p> <p>GPA in core engineering courses (5%)</p> <p>Sending institution accreditation (1%)</p> <p>High school class rank (1%)</p>	<p><b>Institutional Culture <sup>2</sup></b></p> <p>Peer Mentoring (22%)</p> <p>Faculty Mentoring (11%)</p> <p>Supportive campus environment (7%)</p> <p>Right to fail policies (1%)</p>	<p><b>Academic Advising <sup>2</sup></b></p> <p>Specialized transfer academic advising (60%)</p> <p>Transfer specific orientation (11%)</p> <p>Information available on internet (1%)</p> <p>Review of mid-semester grades (1%)</p>
<p><b>Post-Transfer Academics <sup>3</sup></b></p> <p>First fall credit hours (5%)</p> <p>First fall GPA (2%)</p> <p>First spring credit hours (1%)</p> <p>First spring GPA (1%)</p> <p>Withdrawing from an engineering course (1%)</p>	<p><b>Student Integration <sup>3</sup></b></p> <p>Social integration (18%)</p> <p>Interaction with faculty (10%)</p> <p>Interaction with peers (6%)</p> <p>Undergraduate research (5%)</p> <p>Campus involvement (4%)</p> <p>Learning communities (2%)</p>	<p><b>Goals and Commitments <sup>3</sup></b></p> <p>Motivation (7%)</p> <p>Number of hours worked per week (2%)</p> <p>Degree goals (1%)</p>	

<sup>1</sup> Student-Influenced

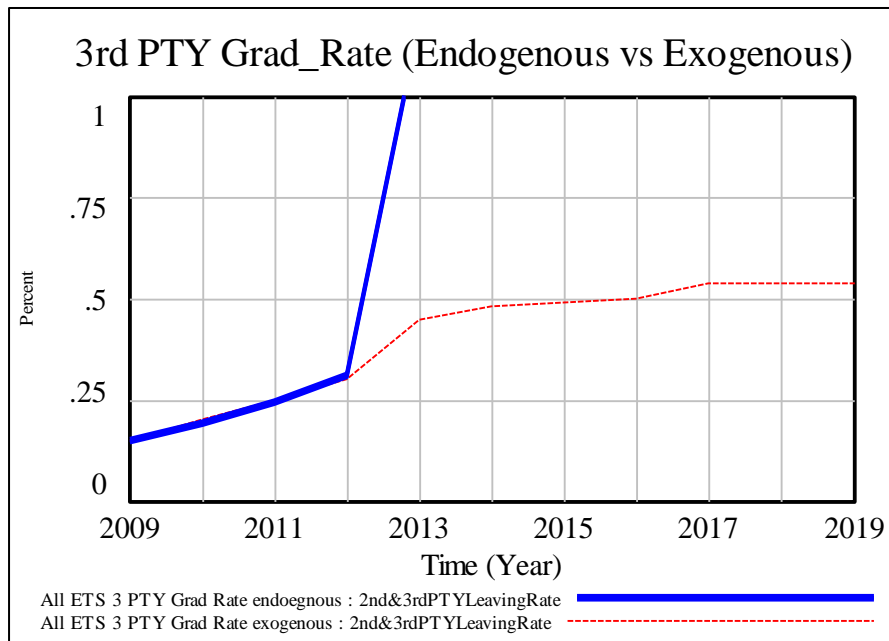
<sup>2</sup> Institution-Influenced

<sup>3</sup> Student- and Institution-Influenced

Specifically, service quality can be linked to factors in the institutional culture and academic advising categories. As the institution improves factors such as *specialized transfer academic advising, mentoring, and providing a supportive campus environment*, they are able to better retain engineering transfer students. This finding reinforces the literature that indicate institutions play a large role in engineering transfer student persistence, it is not only related to student characteristics and their preparation prior to transferring (Darrow & Laanan, 2012; Jackson, Starobin, & Laanan, 2013; Jones & Waggenpack, 2015).

The second leaving pattern includes the students graduating in the third PTY. The SD model demonstrated an information quality component that affected change within this variable. Figure 6.7 provides the change in the third PTY graduation rates over time. Similar to Figure 6.5, this graph also represents actual years rather than cohort years. The students that entered in 2009 are represented in 2011 and so forth.

Figure 6.7 Graduation Rate in the Third Post-Transfer Year



Through 2014, there is a gradual increase in the graduation rate for the third PTY. This represents the admission cohorts from 2009 through 2011. It is important to note that this is not a cumulative graduation rate. The third PTY graduation rate is determined by the number of graduates in that year divided by the number of students that continued into the third PTY. This provides a more accurate method to assess the data at a particular point in time.

The goal-seeking feedback loop linked to information quality provides an explanation for this gradual increase. An overall threshold for students not graduating in four years was set to 25%, and this was compared to the simulated percentage of students not graduating in four years. Based on differences between these values, the university exerts more or less effort to their information quality for engineering transfer students. As the effort increases, the information quality increases. However, as mentioned previously, there is a delay between when the institution implements a change and when the change affects the system. The time to change for this component is also two years. This provides a gradual increase of third PTY graduation rate. The change in enrollment management policies did not impact the percentage of students that were able to graduate if they continued to the third year. This points to a strong need for institutions to invest their effort into retaining students through their third post-transfer year. In addition, the information quality they provide to students affects their ability to graduate in three years rather than four. Information quality can be linked to multiple factors identified in the *academic advising* category in Figure 6.4. Specifically, specialized transfer academic advising and the availability of information on the web can lead to improving the ability for students to graduate in three years. These factors affect the student's ability to better plan their time at the receiving institution and avoid decisions that could delay their graduation (Brawner & Mobley, 2016; Jones & Waggenpack, 2015).

The time delays in both feedback loops represent the amount of time needed for a change by Institution Alpha to affect the system. This time delay includes the time needed to recognize the issue, determine the appropriate solutions, and implement the solutions. Once the solutions are implemented, it also takes times for the affected cohort to pass through the system. This finding can help bring awareness to the length of time needed to adjust student persistence and indicates institutions should be cautious in deciding the effectiveness of solutions too early.

#### 6.5.1 Limitations

This model has two main limitations. First, this model uses an aggregated representation of factors affecting engineering transfer student persistence in the service quality and information quality feedback loops. These loops were informed by existing literature from Authors (Under Review), however, they encapsulate several of the institution-influenced factors, without identifying specific factors and their effect. An important progression for the next iteration of this model would be to further delineate these individual factors and demonstrate their effect on the system. Second, this model focuses on the entire population of engineering transfer students. As shown by Authors (Under Review), there are sub-groups of engineering transfer students that have differing transitions to the institution, as well as varying graduation rates. Further development of the model is needed to include the multiple sub-groups.

#### 6.6 Conclusions

This is the first attempt to apply a system dynamics methodology to student persistence and provide a feedback perspective to understanding factors affecting engineering transfer student persistence. The aging chain structure of this model follows students from their admission to the institution through departure of the system in a four-year timeframe. The model has two main contributions by highlighting two conceptual insights into understanding persistence of transfer

students. First, research often focuses on exogenous factors such as student demographics and pre-transfer academic performance. However, this model demonstrates that endogenous variables create a significant impact on engineering transfer student persistence. Two balancing loops alter the level of effort the university commits to their quality of service to this population, as well as the quality of information they provide. This supports previous literature and provides institutions with a conceptual view of how those factors contribute to improving engineering transfer student persistence.

Second, the strength of each feedback loop is dependent on the time needed for a change in effort to be realized. Demonstrating that these changes have a time delay is an important research finding. Often decision makers do not consider the time delays of an intervention and will continue making changes to reduce the disparity between the desired and actual state of a system, which results in oscillations and instability (Sterman, 2000). A delay of two years was found for decisions related to both service quality and information quality. This indicates that the institution should review the effects of any intervention two years after initiation, and should be careful not to implement multiple interventions at once.

This exploratory SD model provides practitioners with insights into where changes can have the largest effect, but also demonstrates the significance of time delays in the implementation of a change and the affect it will have on the system. The methodology also provides researchers with a new tool that can be expanded to include additional factors and become more robust as they continue to learn more about this student population.

While the SD model was designed for a specific institution and student type, it represents a standard progression of students through the undergraduate student pipeline. The overall structure of model can be used for any institution and any student type. Adjustments would need

to be made to the parameters and the model could be made to be more robust by including additional variables. Ultimately, this work provides a new direction to better understand student persistence and determine the most effective ways to affect change in the system.

## 6.7 Acknowledgements

This material is based on work supported by the National Science Foundation Grant No. 1712089. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

## References

American Society for Engineering Education (ASEE). (2017). *Engineering by the Numbers*.

Washington, D.C.

Andalib, M. A. (2019). Simulation of the leaky pipeline: Gender diversity in US K-graduate education. *Journal of Simulation*. pp. 1-13.

Authors. (Under Review).

Brawner, C. & Mobley, C. (2016). Advising matters: engineering transfer students transition experiences at five institutions. *International Journal of Engineering Education*. Vol. 32, No. 6, pp. 2446-2459.

Darrow, M. & Laanan, F. (2012). Engineering transfer student leavers: voices from the sidelines of the engineering playing field. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.

Aspen Institute, Community College Research Center, Public Agenda, and Sova Solutions (2017). *Tackling Transfer: A Guide to Convening Community Colleges and Universities to Improve Transfer Student Outcomes*. Washington, DC: Authors.

- Fayer, S., Lacey, A., & Watson, A. (2017). STEM occupations: past, present, and future. Spotlight on Statistics. *U.S. Bureau of Labor Statistics Spotlight on Statistics*. Retrieved February 2019 from <https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf>
- Forrester, J. (1961). *Industrial Dynamics*. The M.I.T. Press. Cambridge, MA.
- Forrester, J. (1998). *Designing the future*. Address at Universidad de Sevilla. Sevilla, Spain.
- Frances, C. (2000). Using system dynamics as a tool for decision making in higher education management – U.S. experience. In M. Kennedy (Ed.) *Selected Papers Presented at an International Seminar on “Using System Dynamics as a Tool for Decision Making in Higher Education Management”*. Society for Research into Higher Education, South Bank University Technical Report. Royal Society, London and South Bank University.
- French, B., Immekus, J., & Oakes, W. (2003). A structural model of engineering student success and persistence. *33<sup>rd</sup> Annual Frontiers in Education Conference*. Westminster, CO.
- Ghaffarzadegan, N., & Larson, R. C. (2018). SD meets OR: a new synergy to address policy problems. *System Dynamics Review*, Vol. 34, No. 1-2, pp. 327-353.
- Ghaffarzadegan, N., Larson, R., & Hawley, J. (2016). Education as a complex system. *Systems Research and Behavioral Science*. Vol 34, Issue 3, pp. 211-215.
- Ghaffarzadegan, N., & Xu, R. (2018). Late retirement, early careers, and the aging of US science and engineering professors. *PloS one*. Vol. 13, No. 12, e0208411.
- Glass, J. C., & Harrington, A. R. (2002). Academic performance of community college transfer students and “native” students at a large state university. *Community College Journal of Research and Practice*, 26, 415-430. doi: 10.1080/0277677029141774.

- Groff, J. (2013). Dynamic systems modeling in education system design & policy. *Journal of New Approaches in Educational Research*. Vol. 2, No. 2, pp 72-81.
- Habley, W., Bloom, J., & Robbins, S. (2012). *Research-Based Strategies for College Student Success*. Hoboken, NJ: Wiley.
- Homer JB. 2012. Partial-model testing as a validation tool for system dynamics (1983). *System Dynamics Review*. Vol. 28, No. 3, pp. 281– 294.
- Hossler, D., Shapiro, D., Dundar, A., Ziskin, M., Chen, J., Zerquera, D., & Torres, V. (2012). *Transfer and Mobility: A National View of Student Movement in Postsecondary Institutions, Fall 2006 Cohort (Signature Report No. 2)*. Herndon, VA: National Student Clearinghouse Research Center.
- Ishitani, T. (2008). How do transfers survive after “transfer shock”? A longitudinal study of transfer student departure at a four-year institution. *Research in Higher Education*, 49, 403-419.
- Jackson, D., Starobin, S., & Laanan, F. (2013). The shared experiences: facilitating successful transfer of women and underrepresented minorities in stem fields. *New Directions for Higher Education*. Vol. 2013, No. 162, pp. 69-76.
- Jones, S. & Waggenspack, W. (2015). BRCC to LSU engineering pathway to success. *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- Jordan, S. (1992). Enrolment Demand in Arizona Policy Choices and Social Consequences. *New Direction for Institutional Research*. No. 76.

- Kennedy M. 2011. A review of system dynamics models of educational policy issues. *Proceedings of 24th International Conference of System Dynamics Society*. Washington DC, USA.
- Lewis, C. (1982). *Industrial and Business Forecasting Methods*. Butterworths Publishing. London, 40.
- Oliva R, Kallenberg R. 2003. Managing the transition from products to services. *International Journal of Service Industry Management*. Vol. 14, No. 2, pp. 160– 172.
- Ossimitz, G. & Mrotzek, M. (2008). The basics of system dynamics: discrete vs. continuous modeling of time. *Proceedings from the 2008 International System Dynamics Conference*. Athens, Greece.
- President’s Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Author.
- Robledo, L. (2013). A dynamics enrollment simulation model for planning and decision-making in a university. (Doctoral Dissertation.) Retrieved from the University of Central Florida Digital Repository.
- Sass, D., Castro-Villarreal, F., Wilkerson, S., Guerra, N., & Sullivan, J. (2018). A structural model for predicting student retention. *The Review of Higher Education*. Vol. 42, No. 1, pp. 103-135.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Bhimdiwali, A., Nathan, A., & Youngsik, H. (2018). *Transfer and Mobility: A National View of Student Movement in Postsecondary Institutions, Fall 2011 Cohort* (Signature Report No. 15). Herndon, VA: National Student Clearinghouse Research Center.

Sullivan, M., de Cohen, C., Barna, M., Orr, M., Long, R., & Ohland, M. (2012). Understanding engineering transfer students: demographic characteristics and educational outcomes. *2012 IEEE Frontiers in Education (FIE) Conference Proceedings*. Seattle, WA.

Sterman, J. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin/McGraw-Hall. Boston, MA.

Tobolowsky, B. & Cox, B. (2012). Rationalizing neglect: an institutional response to transfer students. *The Journal of Higher Education*. Vol. 83, No. 3, pp. 389-410.

## **Chapter 7**

### **Conclusions**

Improving engineering persistence rates has become an important research topic in recent years with a significant amount of interest from researchers and practitioners. However, much of the research focuses on first-time, full-time engineering students, which are those that begin their post-secondary education at a four-year institution. There is significantly less research that considers persistence of engineering transfer students, which are students that begin their post-secondary education at a two-year or four-year institution and transfer to a four-year institution to complete the bachelor's degree. The majority of existing research on engineering transfer students focuses on creating pathways for transfer students, specifically from two-year institutions to four-year institutions. While creating these pathways is important, the literature lacks a significant focus on persistence of these students after they have completed the transfer. This research focused on the post-transfer experience and aimed to determine factors that affect engineering transfer student persistence, evaluate differences between sub-groups of engineering transfer students, and develop a model of persistence using a non-linear methodology to better understand the movement of engineering transfer students from their point of admission to when they exit the system. These objectives were accomplished through a systematic literature review with a thematic synthesis, a quantitative analysis of an institutional dataset, and development of a system dynamics model.

#### **7.1 Comparing the Synthesized Results to the Institutional Findings**

The systematic literature review provided a comprehensive list of factors researchers have identified as affecting engineering transfer student persistence. A total of 34 factors was identified

and these were grouped into seven categories. The factors and categories were also classified as student-influenced or institution-influenced. This classification provided a way to view how each factor or category could be influenced, whether it was from student characteristics or behaviors, or from an institutional change. Some factors were classified as both student-influenced and institution-influenced, indicating both the student and institution could affect change in that factor. Once the literature was synthesized, it was appropriate to complete an empirical analysis and further test the findings from literature. A single institution dataset from a large public southeastern university with a large engineering program was used for this analysis.

The existence of transfer shock was also discussed significantly in the literature. Transfer shock is operationalized by computing the difference between two factors identified in the literature: the transfer GPA and the post-transfer GPA (Hills, 1965). Literature focuses on this occurring in the first post-transfer semester. However, researchers indicate it is not a predictor of graduation, though it can lead to students leaving the institution. Generally, if students experience transfer shock, but continue enrollment, there will not be a long-term effect on their graduation status. Findings in the SLR also pointed towards expanding the knowledge of students' academic performance past the first post-transfer term. Therefore, transfer shock measurements were computed for each of the first three post-transfer terms of enrollment. Findings indicated that, on average, all students experienced a greater level of transfer shock in the second post-transfer term than in the first or third post-transfer terms. The term transfer adjustment was introduced to demonstrate that decrease in GPA was not a temporary result found only in the first post-transfer term, but that it extended into the second and third post-transfer terms as well. The findings also indicate the transfer shock measurements in each of the first three post-transfer terms were statistically significant predictors of graduation within four years. This contradicts previous

findings in the literature, and underscores a need for a better understanding of students' academic performance after the first post-transfer semester and how transfer adjustment affects graduation rates, as well as how it can be influenced by both the student and institution.

Another finding from the SLR was a focus on vertical transfers, which identified a research direction that should examine differences between vertical and lateral transfer students. A significant contribution of the institutional analysis was the disaggregation of engineering transfer students into four sub-groups: lateral in-state, lateral out-of-state, vertical with associate degree, and vertical with no associate degree. The analysis demonstrated these sub-groups experience transfer shock differently and have statistically significant differences in their graduation rates. This could provide a rationale for why the literature has not reached a consensus on how engineering transfer student persistence compares to that of FTFT engineering students. Some indicate they persist at higher rates, while others claim they persist at lower rates. Given the differences between engineering transfer student sub-groups, it is important to identify the types of students in the analysis. Those with a higher population of vertical with no associate degree may see lower graduation rates as compared to FTFT engineering students, while those with a higher population of lateral transfers may see higher rates. While this research originally disaggregated the engineering transfer students into four groups, the findings indicate very little differentiation between the two types of lateral engineering transfer students. As the research moves forward, there should be more granular level of analysis of the differences between lateral transfer students, and vertical engineering transfer student with an associate degree and without an associate degree.

## 7.2 Comparing the Synthesized Results and Institutional Findings to the System Dynamics Model

The results of the literature synthesis and the institutional analysis provided direction for the development of a system dynamics simulation model. Findings from both indicated a need to consider the post-transfer experience of students beyond the first post-transfer year. Therefore, the SD model used an aging-chain structure to demonstrate the movement of engineering transfer students through the system. The model boundary of four years was informed by the literature synthesis and institutional analysis. Students exited the system through leaving engineering, graduating in engineering, or continuing enrollment past four years.

The institutional analysis provided several of the parameter values in the model. The data from this phase was also input into the model for historical references on all variables. Once the aging-chain structure was complete, it was evident there were two key leaving patterns for students that had significant variations. The first leaving pattern is the second post-transfer year leaving rates. This variable represents the percentage of students leaving after the first year but before the third year. Much of the literature focuses on engineering transfer students leaving in the first year, however, the SD model highlights the second post-transfer year as a more significant exit point. This confirms the findings from both the research synthesis and institutional analysis that institutions should explore post-transfer academics beyond the first post-transfer year. A service quality component was found to be a driver for this behavior based on a leaving rate threshold. As the percentage of students leaving increased towards the threshold, the university's effort to improve their service quality for students increased. As the level of effort increases, the service quality increased, and the percentage of students leaving in the second post-transfer year

decreased. The service quality represents several factors identified in the research synthesis, specifically factors in the *academic advising* and *institutional culture* categories.

The second key leaving pattern included the third post-transfer graduation rates. This rate represents the percentage of students that continued to the third post-transfer year and graduated in the third post-transfer year. This rate had a significant amount of growth. An information quality component was found to be a driver for this behavior based on a threshold for the percentage of students not graduated in four years. As the percentage of students who did not graduate in four years increased towards the threshold, the university's effort to improve their information quality for students increased. As the level of effort increased, the information quality increased, and the percentage of students graduating in the third post-transfer year increased. The information quality represents several factors identified in the research synthesis, specifically factors in the *academic advising* category.

### 7.3 Contributions

This research provides several important contributions to the scholarly body of knowledge in engineering transfer student persistence, as well as introduces new applications of management systems engineering techniques. Gaps identified in the literature through the SLR and thematic synthesis provided direction for the next phases of the research which included several new findings. First, this research introduced a literature-based conceptual framework for engineering transfer student persistence. The updated framework addresses limitations in the current persistence frameworks that were developed based on first-time, full-time students. The framework includes many of the factors in current persistence frameworks, but adds several identified in the literature that are unique to engineering transfer students. Second, findings from this research demonstrated that transfer shock is not a one-time occurrence in the first post-transfer

term, and coined the term transfer adjustment as a more representative descriptor. The institutional analysis found that students experience the greatest degree of transfer adjustment in the second post-transfer term of enrollment. Third, this research found that engineering transfer student sub-groups transition differently to the institution and have differential 4-year graduation rates. Few of the publications identified through the SLR discussed the experience of lateral transfer students. This research disaggregated engineering transfer students into four sub-groups that included lateral in-state, lateral out-of-state, vertical with associate degree, and vertical with no associate degree. After the analysis, these two lateral sub-groups were condensed into one sub-group, resulting in three total sub-groups of engineering transfer students – lateral, vertical with an associate degree, vertical without an associate degree. This finding confirms that engineering transfer students should not be considered as a homogenous population.

Two methodologies, systematic literature review and system dynamics, are introduced to the student persistence research area. The SLR methodology is widely used in medical and business fields, and is identified as an appropriate methodology for engineering education researchers (Borrego, Foster, and Froyd, 2014). Additionally, the SD methodology has also been applied in numerous fields, including business, medicine, and economic behavior (Forrester, 1998), and is identified as an appropriate methodology for educational settings (Ghaffarzadegan et al., 2017). Both methodologies are often used in management systems engineering to assist with defining and designing complex management systems. As engineering education and enrollment managers seek to understand the complexities of student throughput and develop effective persistence strategies, an engineering design and analysis process and methodology should be considered.

#### 7.4 Implications for practice

This research provides practitioners in the fields of engineering education and enrollment management with key insights to the engineering transfer student population that can help shape future policies and programming. A review of the existing literature provides a comprehensive list of factors that affect engineering transfer student persistence. These factors were organized into seven categories that includes student characteristics, pre-transfer academics, post-transfer academics, goals and commitments, student integration, institutional culture, and academic advising. These categories were also identified as student-influenced, institution-influenced, or influenced by both the student and institutions. This synthesis of the literature provides practitioners with an explicit list of factors they can influence. It also suggests themes that span across the categories that can help shape future strategies. Financial support was identified as a significant factor that affects engineering transfer student persistence through decreasing the number of hours worked per week and increasing the social integration of students to the institution. Creating a positive institutional culture for engineering transfer students can influence students' aspirational goals and motivations for pursuing an engineering degree which are important intrinsic drivers for this population.

Practitioners should also determine the types of engineering transfer students at their institution, and better understand differences in the transition experiences of those students. This knowledge can inform more strategic, longitudinal programming and decision-making that considers student persistence beyond just the first post-transfer year, and accounts for the different transitioning experiences across the engineering transfer student sub-groups. The exploratory SD model presented in this research introduces a new tool for practitioners to better understand student persistence, provides insights into where changes can have the largest effect, and demonstrates the

significance of time delays in the implementation of a change and the affect it will have on the system.

### 7.5 Limitations

One limitation to this research relates to limitations with the SLR methodology. The search results are limited to those indexed within the platforms used in the search strategy. Multiple platforms were selected to increase the number and types of publication, however, any publications not indexed within one of the selected platforms would not be captured in the search. In addition to the limitation of the SLR methodology, there are also limitations related to the institutional analysis. The analysis only includes one institution which limits the generalizability of the results. Additionally, a large subset of students were missing data which resulted in fewer students that were included in the analysis. The institutional analysis also only considered some of the factors identified through the SLR and thematic analysis which limits the empirical comparison.

There are also limitations to the SD model. Model development will often include a group model build component or seek a subject-matter expert reviewer. The researcher has expertise in the subject matter, however, the researcher's mental models and biases could have influenced the model. Additionally, the model includes an aggregated representation of factors affecting engineering transfer student persistence in the service quality and information quality feedback loops. Expanding the feedback loops to included individual factors would provide a greater insight into specific drivers within the system. This model also focuses on the entire population of engineering transfer students and does not differentiate the sub-groups of engineering transfer students. Further development of the model is needed to include the multiple sub-groups.

## 7.6 Future Work

There are several directions for future work in this research area. First, after the first post-transfer year, no further academic performance-based factors were found in the publications identified through the SLR. However, the findings from the institutional analysis in this research demonstrated transfer shock extended beyond the first post-transfer term. The SD simulation model pointed to the second post-transfer year as the largest exit point for students that leave engineering. Future empirical studies should examine second post-transfer year academic performance-based factors as a means to reduce the number of engineering transfer students leaving in the second post-transfer year.

Second, only one publication identified in the SLR explicitly considered the differences between vertical and lateral engineering transfer students. However, findings from the institutional analysis demonstrated key differences between these types of engineering transfer students. Lateral students were found to experience less transfer shock and have higher 4-year graduation rates than the vertical transfer students. These results suggest future empirical analysis should include a more disaggregated view of engineering transfer students. This would allow institutions and researchers to better understand the unique challenges faced by each type and provide a direction for developing appropriate programming to assist with their challenges.

Third, publications identified in the SLR used several persistence frameworks that were developed for first-time, full-time students and do not include several of the unique characteristics of engineering transfer students. A literature-based conceptual framework was introduced in this research as an expansion of Tinto's (1993) model of student integration. However, future research is needed to validate this framework.

Lastly, the SD model is an exploratory model that can be expanded to include a more comprehensive view of the system. The engineering transfer student sub-groups could be included, and more of the individual factors identified through the SLR process could be included. This would require additional means of information gathering, such as group model building, focus groups, and surveys.

## References

- Allen, T. & Zhang, Y. (2016). Dedicated to their degrees: adult transfer students in engineering baccalaureate programs. *Community College Review*. Vol. 44, No. 1, pp. 70-86.
- Almatrafi, O., Johri, A., Rangwala, H., & Lester, J. (2017). Retention and persistence among stem students: a comparison of direct admit and transfer students across engineering and science. *2017 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Columbus, OH.
- Alting, A., Delale, F., & Barba, J. (2013). Bridges to engineering: success for transfers. *2013 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Atlanta, GA.
- American Society for Engineering Education (ASEE). (2016). Profiles of Engineering and Engineering Technology Colleges. Washington, D. C.
- American Society for Engineering Education (ASEE). (2017). *Engineering By The Numbers*. Washington, D. C.
- Andalib, M. A. (2019). Simulation of the leaky pipeline: Gender diversity in US K-graduate education. *Journal of Simulation*. pp. 1-13.
- Anderson, M., Perez, L., Jones, D., Zafft, C. (2011). Success factors for students transferring into undergraduate engineering degree programs. *2011 Frontiers in Education Conference (FIE) Proceedings*. Rapid City, SD.
- Anderson-Rowland, M. & Grierson, A. (2010). Evaluating a university/community college collaboration for encouragement of engineering and computer science transfer students. *2010 American Society for Engineering Education (ASEE) Proceedings*. Louisville, KY.

- Anderson-Rowland, M. & Rodriguez, A. (2015). Sophomore transfers: who are they and what support do they need? *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- Anderson-Rowland, M. (2000). Understanding engineering students for better recruitment strategies: A four-year study. *2000 Frontiers in Education (FIE) Conference Proceedings*. Kansas City, MO.
- Anderson-Rowland, M. (2009). An academic scholarship program for transfer students in engineering and computer science: a five-year summary. *2009 American Society for Engineering Education (ASEE) Conference Proceedings*. Austin, TX.
- Anderson-Rowland, M. (2011). Reducing GPA shock for engineering and computer science community college transfer students. *2011 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Vancouver, B.C., Canada.
- Anderson-Rowland, M. (2013). Expectations and realities for community college engineering transfers at a large university. *2013 IEEE Frontiers in Education (FIE) Conference*. Oklahoma City, OK.
- Anderson-Rowland, M. (2013). Transfer experience for upper division engineering and computer science students. *2013 American Society for Engineering Education (ASEE) Annual Conference*. Atlanta, GA.
- Anderson-Rowland, M., Rodriguez, A., & Grierson, A. (2015). Motivated engineering transfer students/step after six years. *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.

- Anderson-Rowland, M., Rodriguez, A., Hall, R., McBride, P., Pangasa, R., Saber, J., Vangilder, C., & Grierson, A. (2012). Leveraging S-STEM scholarship programs. *2012 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. San Antonio, TX.
- Aspen Institute, Community College Research Center, Public Agenda, and Sova Solutions (2017). *Tackling Transfer: A Guide to Convening Community Colleges and Universities to Improve Transfer Student Outcomes*. Washington, DC: Authors.
- Astin, A. (1999). Student involvement: A developmental theory for higher education. *Journal of College Student Development*. Vol. 40, No. 5, pp. 518-29.
- Auerbach, J. & Williams, D. (2013). The ties program: a transfer initiative for engineering students. *2013 IEEE Frontiers in Education (FIE) Conference*. Oklahoma City, OK.
- Authors. (Under Review). *Journal of Engineering Education*.
- Bahr, P., Toth, C., Thirolf, K., & Massé, J. (2013). A review and critique of the literature on community college students' transition processes and outcomes in four-year institutions. In: Paulsen, M (eds). *Higher Education: Handbook of Theory and Research*. Vol. 28, pp. 459-511. Springer, Dordrecht.
- Barnes, W. (1991). A comparison of BSET transfer students from ABET--accredited and non-accredited community colleges. 1991 Frontiers in Education (FIE) Conference Proceedings. West Lafayette, IN.
- Bayles, T. (2016). A chemical engineering success course for transfer students. *2016 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. New Orleans, LA.
- Bean, J. & Eaton, S. (2001). The psychology underlying successful retention practices. *J. College Student Retention*. Vol 3, No. 1, pp. 73-89.

- Bean, J. & Metzner, B. (1985). A conceptual model of non-traditional undergraduate student attrition. *Review of Educational Research*, vol. 55, no. 4, pp. 485-540.
- Bean, J. (1980). Dropouts and turnover: The synthesis and test of a causal model of student attrition. *Research in Higher Education*, vol. 12, no. 2, pp. 155-187.
- Berger, J. B., & Lyon, S. C. (2005). Past to present: A historical look at retention. In A. Seidman (Ed.), *College student retention: Formula for student success* (pp. 1-30). Westport, CT: Praeger Publishers.
- Boeing, G. (2016). Visual Analysis of Nonlinear Dynamical Systems: Chaos, Fractals, Self-Similarity and the Limits of Prediction. *Systems*, 4(4), 37.
- Bohanna, D. & Ebbers, L. (2016). Academic and social experiences of female community college transfer students in engineering fields at midwestern university. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- Bonsangue, M., Cadwalladerolsker, T., Fernandez-Weston, C., Filowitz, M., Hershey, J., Moon, H., Renne, C., Sullivan, E., Walker, S., Woods, R., & Engelke, N. (2013). The effect of supplemental instruction on transfer student success in first semester calculus. *Learning Assistance Review*. Vol. 18, No. 1, pp. 61-74.
- Borrego, M., Foster, M., & Froyd, J. (2014). Systematic literature reviews in engineering education and other developing interdisciplinary fields. *Journal of Engineering Education*. Vol. 103, No. 1, pp. 45-76.
- Brawner, C. & Mobley, C. (2016). Advising matters: engineering transfer students transition experiences at five institutions. *International Journal of Engineering Education*. Vol. 32, No. 6, pp. 2446-2459.

- Braxton, J. & Lee, S. (2005). Toward reliable knowledge about college student departure. In A. Seidman (Ed.) *College Student Retention: Formula for student success*. Greenwood Publishing Group.
- Britten, N., Campbell, R. Pope, C., Donovan, J., Morgan, M., & Pill, R. (2002). Using meta-ethnography to synthesise qualitative research: a worked example. *Journal of Health Services Research & Policy*. Vol. 7, No. 4, pp. 209-215.
- Bronfenbrenner, U. (2005). Ecological systems theory. In U. Bronfenbrenner (Ed.). *Making human beings human: Bioecological perspectives on human development* (pp. 106-173). Thousand Oaks, CA: Sage.
- Brown, A. (1993). *Transfer retention at city college in engineering (TRACC) final report, September 30, 1992 – September 29, 1993*. Washington, DC. U.S. Department of Education.
- Cabrera, A., Nora, A., & Castaneda, M. (1993). College persistence: structural equations modeling test of an integrated model of student retention. *The Journal of Higher Education*, 64(2), 123-139. doi:10.2307/2960026
- Carlan, P. & Byxbe, F. (2000). Community colleges under the microscope: an analysis of performance predictors for native and transfer students. *Community College Review*. Vol. 28, No. 2, pp. 77-93.
- Cejda, B., Kaylor, A., Rewey, K. (1998). Transfer shock in an academic discipline: The relationship between students' major and their academic performance. *Community College Review*. Vol. 26, No. 3, pp. 1-13.
- Clinedinst, M. & Koranteng, A. (2017). *State of College Admission*. National Association for College Admission Counseling.

- Concannon, J. & Barrow, L. (2009). A cross-sectional study of engineering students' self-efficacy by gender, ethnicity, year, and transfer status. *Journal of Science Education and Technology*. Vol. 18, No. 2, pp. 163-172.
- Cosentino, C., Sullivan, M., Gahlawat, N., Ohland, M., & Long, R. (2014). Black engineering transfer students what explains their success? *2014 IEEE Frontiers in Education (FIE) Conference Proceedings*. Madrid, Spain.
- Cotts, E., Fang, J., Jones, W., Klotzkin, D., Myers, G., & White, B. (2016). A STEM program focused on transfer student success at Binghamton University. *2016 IEEE Frontiers in Education (FIE) Conference Proceedings*. Eerie, PN.
- Coyote, R. (2013). The relevance of career aspirations for transfer students persisting in science, technology, engineering and math disciplines. (Doctoral Dissertation). University of Arizona.
- D'Amico, M., Dika, S., Elling, T., Algozzine, B., & Ginn, D. (2014). Early integration and other outcomes for community college transfer students. *Research in Higher Education*. Vol, 55, Issue 4, pp. 370-399.
- Darrow, M. & Laanan, F. (2012). Engineering transfer student leavers: voices from the sidelines of the engineering playing field. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- Demetriou, C. & Schmitz-Sciborski, A. (2011). Integration, motivation, strengths and optimism: Retention
- Dowd, A., Pak, J., & Bensimon, E. (2013). The role of institutional agents in promoting transfer access. *Education Policy Analysis Archives*. Vol. 21, No. 15.
- Estep, T. (2016). The graduation gap and socioeconomic status: Using stereotype threat to explain graduation rates. *The SES Indicator*. Vol. 9, No. 3. American Psychological Association.

- Evans, H. & Mody-Pan, P. (2010). Using an adaptive Tinto framework to interpret successes of two-year institutions in retaining engineering students. 2010 *American Society for Engineering Education (ASEE) Conference Proceedings*. Louisville, KY.
- Fayer, S., Lacey, A., & Watson, A. (2017). STEM occupations: past, present, and future. Spotlight on Statistics. *U.S. Bureau of Labor Statistics Spotlight on Statistics*. Retrieved February 2019 from <https://www.bls.gov/spotlight/2017/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future/pdf/science-technology-engineering-and-mathematics-stem-occupations-past-present-and-future.pdf>
- Field, A., Miles, J., Field, Z. (2012). *Discovering Statistics Using R*. SAGE Publications. Thousand Oaks, CA.
- Fisher, M., Qureshi, H., Hardyman, W., Homewood, J. (2006). *Using Qualitative Research in Systematic Reviews: Older People's Views of Hospital Discharge*. London: Social Care Institute for Excellence, London, UK.
- Ford, D., Rees, P., & Rubin, K. (2015). The impact of federally funded scholarship programs on the success of transfer students at a public engineering college. 2015 *American Society for Engineering Education (ASEE) Conference Proceedings*. Seattle, WA.
- Forrester, J. (1961). *Industrial Dynamics*. The M.I.T. Press. Cambridge, MA.
- Forrester, J. (1998). *Designing the future*. Address at Universidad de Sevilla. Sevilla, Spain.
- Frances, C. (2000). Using system dynamics as a tool for decision making in higher education management – U.S. experience. In M. Kennedy (Ed.) *Selected Papers Presented at an International Seminar on "Using System Dynamics as a Tool for Decision Making in Higher Education Management"*. Society for Research into Higher Education, South Bank University Technical Report. Royal Society, London and South Bank University.

- Freedman, D. (2005). *Statistical Model: Theory and Practice*. Cambridge University Press. Cambridge, MA.
- French, B., Immekus, J., & Oakes, W. (2003). A structural model of engineering student success and persistence. *33<sup>rd</sup> Annual Frontiers in Education Conference*. Westminster, CO.
- Georgetown University Center on Education and the Workforce. (2013). *Recovery: Job Growth and Education Requirements*. Retrieved from [https://cew.georgetown.edu/wp-content/uploads/2014/11/Recovery2020.FR\\_.Web\\_.pdf](https://cew.georgetown.edu/wp-content/uploads/2014/11/Recovery2020.FR_.Web_.pdf)
- Ghaffarzadegan, N., & Larson, R. C. (2018). SD meets OR: a new synergy to address policy problems. *System Dynamics Review*, Vol. 34, No. 1-2, pp. 327-353.
- Ghaffarzadegan, N., & Xu, R. (2018). Late retirement, early careers, and the aging of US science and engineering professors. *PloS one*. Vol. 13, No. 12, e0208411.
- Ghaffarzadegan, N., Larson, R., & Hawley, J. (2016). Education as a complex system. *Systems Research and Behavioral Science*. Vol 34, Issue 3, pp. 211-215.
- Ghaffarzadegan, N., Larson, R., & Hawley, J. (2016). Education as a complex system. *Systems*
- Glass, J. C., & Harrington, A. R. (2002). Academic performance of community college transfer students and “native” students at a large state university. *Community College Journal of Research and Practice*, 26, 415-430. doi: 10.1080/0277677029141774.
- Glynn, J. (2019). Persistence: The Success of Students Who Transfer from Community Colleges to Selective Four-Year Institutions. Lansdowne, VA: Jack Kent Cooke Foundation.
- Gonzalez, F. & Pinzon, G. (2014). A stem transfer and retention program at Texas A&M international university. *2014 American Society for Engineering Education (ASEE) Conference Proceedings*. Indianapolis, IN.

- Graham, S. & Dallam, J. (1986). Academic probation as a measure of performance: contrasting transfer students to native students. *Community/Junior College Quarterly of Research and Practice*. 10. 23-24.
- Gupta, S., Moon, J., Melton, R., Kuhl, M., Johnson, D., Dunn, T., Lee, J., Foltz, F., & Garrick, R. (2018). Scholarship programs for vertical transfers in engineering and engineering technology. *2018 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Salt Lake City, UT.
- Habley, W., Bloom, J., & Robbins, S. (2012). *Increasing Persistence: Research-Based Strategies for College Student Success*. San Francisco, CA: Jossey-Bass.
- Habley, W., Bloom, J., & Robbins, S. (2012). *Research-Based Strategies for College Student Success*. Hoboken, NJ: Wiley.
- Hagler, L. & Sheridan, D. (2015). Exploring the academic and social experiences of Latino engineering community college transfer students at a 4-year institution: a qualitative research study. (Doctoral Dissertation). Retrieved from Northeastern University Digital Repository.
- Hennessey, N. (2019). Overcoming shock: An examination of transfer shock and student resiliency. (Master's Thesis). Retrieved from the University of Arizona Campus Repository.
- Higgins, J. & Green, S. (Eds). (2011). Chapter 4: Guide to the contents of a Cochrane protocol review. *Cochrane Handbook for Systematic Reviews of Interventions*. The Cochrane Collaboration.
- Hills, J. (1965) Transfer shock: The academic performance of the transfer student. *The Journal of Experimental Education*, Vol. 33, No. 3.
- Hogarth, R. (1987). *Judgement and Choice*, 2<sup>nd</sup> ed. Chichester, England: John Wiley and Sons.

- Holahan, C., Green, J., & Kelley, P. (1983). A 6-year longitudinal analysis of transfer student performance and retention. *Journal of College Student Personnel*. Vol. 24, Issue 4.
- Homer JB. 2012. Partial-model testing as a validation tool for system dynamics (1983). *System Dynamics Review*. Vol. 28, No. 3, pp. 281– 294.
- Hossler, D. & Bontrager, B. (2015). *Handbook of Strategic Enrollment Management*. San Francisco: Jossey-Bass an Imprint of Wiley.
- Hossler, D., Shapiro, D., Dundar, A., Ziskin, M., Chen, J., Zerquera, D., & Torres, V. (2012). *Transfer and Mobility: A National View of Student Movement in Postsecondary Institutions, Fall 2006 Cohort (Signature Report No. 2)*. Herndon, VA: National Student Clearinghouse Research Center.
- Hutton, R. & Panter, A. (2015). Modeling bachelor's degree completion rates of North Carolina community college transfer students using a discrete-time survival analysis. (Doctoral Dissertation). Retrieved from the University of North Carolina.
- Illinois Community College Board. (1986). *Transfer study: a five-year study of students transferring from Illinois two-year colleges to Illinois senior colleges/universities in the fall of 1979*. Springfield, IL: U.S. Department of Education. Retrieved from <https://eric.ed.gov/?id=ED270148>.
- Institute for Education Sciences, National Center for Education Statistics. (2013.) Percentage of recent high school completers enrolled in 2-year and 4-year colleges, by income level: 1975 through 2012. Available at [http://nces.ed.gov/programs/digest/d13/tables/dt13\\_302.30.asp](http://nces.ed.gov/programs/digest/d13/tables/dt13_302.30.asp).
- Ishitani, T. (2008). How do transfers survive after “transfer shock”? A longitudinal study of transfer student departure at a four-year institution. *Research in Higher Education*, 49, 403-419.

- Ivins, T., Copenhaver, K., & Koclanes, A. (2017). Adult transitional theory and transfer shock in higher education: practices from literature. *Reference Services Review*. Vol. 45, Issue 2, pp. 244-257. doi.org/10.1108/RSR-08-2016-0048
- Jackson, D. & Laanan, F. (2015). Desiring to fit: fostering success of community college transfer students in STEM. *Community College Journal of Research and Practice*. Vol. 39, No. 5, pp. 132-149.
- Jackson, D., Starobin, S., & Laanan, F. (2013). The shared experiences: facilitating successful transfer of women and underrepresented minorities in stem fields. *New Directions for Higher Education*. Vol. 2013, No. 162, pp. 69-76.
- Jacquez, R., Garland, J., King, J., Auzenne, M., Peralta, S., & Rubio, H. (2005). The minority engineering transfer and articulation (META) program: building stronger pathways and developing student achievement. *2005 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Portland, OR.
- Jefferson, G., Steadman, S. & Dougherty, F. (2013). Transfer student transition: Lessons learned. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.
- Jones, S. & Waggenspack, W. (2015). BRCC to LSU engineering pathway to success. *2015 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Seattle, WA.
- Jordan, S. (1992). Enrolment Demand in Arizona Policy Choices and Social Consequences. *New Direction for Institutional Research*. No. 76.
- Jovanovic, V., Sparkman-Key, N., Cigularov, K., Cigularova, D., & Anthony, B. (2018). Advancing the engineering field: Opportunities to support transfer students. *2018 American*

*Society for Engineering Education (ASEE) Annual Conference Proceedings*. Salt Lake City, UT.

Kampe, J., Edmister, W., Boone, C., & Watford, B. (2008). Transfer students: tailoring a freshman program to their needs. *2008 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Pittsburgh, PA.

Kanter, M., Ochoa, E., Nassif, R., & Chong, F. (2011). Meeting President Obama's 2020 College Completion Goal. Lecture presented at Department of Education. Retrieved from <https://www.ed.gov/news/speeches/meeting-president-obamas-2020-college-completion-goal>.

Kennedy M. 2011. A review of system dynamics models of educational policy issues. *Proceedings of 24th International Conference of System Dynamics Society*. Washington DC, USA.

Knight, D, Bergom, I. Burt, B., & Lattuca, L. (2014). Multiple starting lines: pre-college characteristics of community college and four-year institution engineering students. *2014 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Indianapolis, IN.

Knowles, M., Holton, E., & Swanson, R. (2005). *The adult learner: the definitive classic in adult education and human resource development*. Amsterdam: Elsevier.

Laanan, F. (2004). Studying transfer students, part 1: instrument design and implications. *Community College Journal of Research and Practice*. Vol 28, pp. 331–351.

Laanan, F., Jackson, D., & Darrow, M. (2010). Experiences of engineering transfer students: from community college to university. *2010 American Society for Engineering Education (ASEE) Conference Proceedings*. Louisville, KY.

- Laanan, F., Jackson, D., & Rover, D. (2011). Engineering transfer students: characteristics, experiences, and student outcomes. *2011 American Society for Engineering Education (ASEE) Conference Proceedings*. Vancouver, B.C., Canada.
- Laier, J. & Steadman, S. (2014). Improving transfer student success. *2014 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Indianapolis, IN.
- Lakin, J. & Cardenas Elliott, D. (2016). STEMing the shock: examining transfer shock and its impact on STEM major and enrollment persistence. *Journal of the First-Year Experience & Students in Transition*. Vol. 28, No. 2, pp 9-31.
- Laugerman, M. & Shelley, M. (2013). A structural equation model correlating success in engineering with academic variables for community college transfer students. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.
- Laugerman, M., Rover, D., Shelley, M., & Mickelson, S. (2015). Determining graduation rates in engineering for community college transfer students using data mining. *International Journal of Engineering Education*. Vol. 31, No. 6, pp. 1448-1457.
- Laugerman, M., Shelley, M., Rover, D., & Mickelson, S. (2015). Estimating survival rates in engineering for community college transfer students using grades in calculus and physics. *International Journal of Education in Mathematics, Science and Technology*. Vol. 3, No. 4, pp. 313-321.
- Lee, H. & Schneider, T. (2016). Does post-transfer involvement matter for persistence of community college transfer students? *Community College Journal of Research and Practice*. Vol. 42, No. 2, pp. 77-94.
- Lewis, C. (1982). *Industrial and Business Forecasting Methods*. Butterworths Publishing. London, 40.

- Li, Q, Swaminathan, H. & Tang, J. (2009). Development of a classification system for engineering student characteristics affecting college enrollment and retention. *Journal of Engineering Education*. Vol. 98, No. 4, pp. 361-376.
- Lockwood, P., Hunt, E., Matlack, R., & Kelley, J. (2013). From community college to four-year institution: a model for recruitment and retention. *Community College Journal of Research and Practice*. Vol. 37, No. 8, pp. 613.
- Lopez, C. & Jones, S. (2017). Examination of factors that predict academic adjustment and success of community college transfer students in stem at 4-year institutions. *Community College Journal of Research and Practice*. Vol. 41, No. 3, pp. 168-182.
- Lopez, C. & Laanan, F. (2012). Transfer students in STEM majors at a midwestern university: academic and social involvement factors that influence student success. (Doctoral Dissertation). Retrieved from the Iowa State University Digital Repository.
- Lundberg, T. (2014). Making space and making do: An exploration of the practices that start new majority students towards their educational goals. (Doctoral Dissertation). Retrieved from the University of Wisconsin at Madison.
- Manyaga, F., Sithole, A., & Hanson, S. (2017). Comparison of student retention models in undergraduate education from the past eight decades. *Journal of Applied Learning in Higher Education*. Vol. 7, pp. 29-41.
- Marra, R., Chia-Lin, T., Bogue, B., & Landa Pytel, J. (2015). Alternative pathways to engineering success -using academic and social integration to understand two-year engineering student success. *American Journal of Engineering Education*. Vol. 6, No. 2, pp. 69-84.
- Massi, L., Lancey, P, Nair, U, Straney, R. Georgiopoulos, M., & Young, C. (2012). Engineering and computer science community college transfers and native freshmen students: relationships

- among participation in extra-curricular and co-curricular activities, connecting to the university campus, and academic success. *2012 IEEE Frontiers in Education (FIE) Conference Proceedings*. Seattle, WA.
- Mattis, L., Lancey, P. Nair, U., Straney, R., Georgiopoulos, M., & Young, C. (2012). Engineering and Computer Science Community College Transfers and Native Freshmen Students: Relationships Among Participation in Extra-Curricular and Co-Curricular Activities, Connecting to the University Campus, and Academic Success. *2012 American Society for Engineering Education (ASEE) Conference Proceedings*. San Antonio, TX.
- Mattis, M. & Sislin, J. (2005). *Enhancing the community college pathway to engineering careers*. National Academies Press. Washington, DC.
- McBurnie, J., Campbell, M., & West, J. (2012). Avoiding the second year slump: A transition framework for students progressing through university. *International Journal of Innovation in Science and Mathematics Education*. Vol. 20. No. 2.
- McDowell, C. & Harrell, A. (2009). Easing the transition from the community college to the four-year university. *2009 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Austin, TX.
- McHugh, M. (2013). The chi-square test of independence. *Biochemia medica*. Vol. 23, No. 2, pp. 143-149.
- Mendez, E. & Fraser-Abder, P. (2001). A qualitative case study of Hispanic community college students' transfer and first -year experiences in a college of engineering at a large research public university. (Doctoral Dissertation). Retrieved from the New York University Digital Repository.

- Mickelson, S. & Laugerman, M. (2011). Characteristics of community college transfer students that successfully matriculate and graduate in engineering. *2011 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Vancouver, B.C., Canada.
- Miguel, A. & Abraham, S. (2017). Creating an environment for transfer student success. *2017 American Society for Engineering Education (ASEE) Conference Proceedings*. Columbus, OH.
- Mobley, C & Brawner, C. (2018). “Life prepared me well for succeeding”: The enactment of community college cultural wealth, experiential capital, and transfer student capital by first-generation engineering transfer students. *Community College Journal of Research and Practice*. Vol. 43, No. 5, pp. 353-369.
- Mobley, C. & Brawner, C. (2013). Engineering transfer students' views on orientation and advising. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.
- Mobley, C., Shealy, E., & Brawner, C. (2013). First-generation engineering transfer students: a qualitative study of social and cultural capital. *2013 IEEE Frontiers in Education (FIE) Conference Proceedings*. Oklahoma City, OK.
- Mohd Razali, N. & Wah, Y. (2011). Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *Journal of Statistical Modeling and Analytics*. Vol. 2, No. 1, pp. 21-33.
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D., & the PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Annals of Internal Medicine*. Vol. 141, No. 4, pp. 264-270.

- NACADA: The Global Community for Academic Advising. (2017). NACADA academic advising core competencies model. Retrieved from <https://www.nacada.ksu.edu/Resources/Pillars/CoreCompetencies.aspx>
- Ogilvie, A. (2014). A review of the literature on transfer student pathways to engineering degrees. *2014 American Society for Engineering Education (ASEE) Conference Proceedings*. Indianapolis, IN.
- Ohland, M. & Anderson, T. (2001). SUCCEED (Southeastern University and College Coalition for Engineering Education) Strategic Plan Revision. U.S. Department of Education
- Ohland, M., Camacho, M. Layton, R. Lord, S., & Wasburn, M. (2009). How we measure success makes a difference: Eight-semester persistence and graduation rates for female and male engineering students. *2009 American Society for Engineering Education (ASEE) Conference Proceedings*. Austin, TX.
- Oliva R, Kallenberg R. 2003. Managing the transition from products to services. *International Journal of Service Industry Management*. Vol. 14, No. 2, pp. 160– 172.
- Olson, L., Moll, A., Bullock, D., Jain, A., & Callahan, J. (2016). Support model for transfer students utilizing the STEM scholarship program. *2016 American Society for Engineering Education (ASEE) Conference Proceedings*. New Orleans, LA.
- Ossimitz, G. & Mrotzek, M. (2008). The basics of system dynamics: discrete vs. continuous modeling of time. *Proceedings from the 2008 International System Dynamics Conference*. Athens, Greece.
- Pascarella, E. T., Smart, J.C., and Ethington, C.A. (1986). Long-term persistence of two-year college students. *Proceedings from the 1986 Study of Higher Education Conference*. San Antonio, TX.

- President's Council of Advisors on Science and Technology (PCAST). (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics*. Washington, DC: Author.
- Rendon, L. (1986). A comprehensive strategy to examine and address transfer education. *Conference of the Texas Coordinating Board Proceedings*. Austin, TX.
- Rendon, L. (1994). Validating culturally diverse students toward a new model of learning and student development. *Innovative Higher Education*. Vol. 19, No. 1, pp. 33-51.
- Rhoades, G. (1998). Reviewing and rethinking administrative costs. In J.C. Smart (Ed.). *Higher Education: Handbook of Theory and Research* 9, pp. 111-146. New York: Agathon Press.
- Robledo, L. (2013). A dynamics enrollment simulation model for planning and decision-making in a university. (Doctoral Dissertation.) Retrieved from the University of Central Florida Digital Repository.
- Ryan, R. & Durdella, N., & Navarro, T. (2014). A case study of success: mentoring and supporting underrepresented transfer students in a mechanical engineering program. *2014 American Society for Engineering Education (ASEE) Conference Proceedings*. Indianapolis, IN.
- Sarder, B. (2013). Bridging the gap in transition of students from community colleges to universities. *2013 American Society for Engineering Education (ASEE) Conference Proceedings*. Atlanta, GA.
- Sargent, J. (2017). The U.S. science and engineering workforce: recent, current, and projected employment, wages, and unemployment. *Congressional Research Service Report R43061 Prepared for Members and Committees of Congress*.
- Sass, D., Castro-Villarreal, F., Wilkerson, S., Guerra, N., & Sullivan, J. (2018). A structural model for predicting student retention. *The Review of Higher Education*. Vol. 42, No. 1, pp. 103-135.

- Schlossberg, N. (1984). *Counseling Adults in Transitions*. New York: Springer Publishing Company.
- Scott, T., Thigpin, S., & Bentz, A. (2017). Transfer learning community: overcoming transfer shock and increasing retention of mathematics and science majors. *Journal of College Student Retention: Research, Theory & Practice*. Vol. 19, No. 3, pp. 300-316.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Bhimdiwali, A., Nathan, A., & Youngsik, H. (2018). Transfer and Mobility: A National View of Student Movement in Postsecondary Institutions, Fall 2011 Cohort (Signature Report No. 15). Herndon, VA: National Student Clearinghouse Research Center.
- Shapiro, D., Dundar, A., Huie, F., Wakhungu, P.K., Yuan, X., Nathan, A. & Hwang, Y. (2017). Tracking Transfer: Measures of Effectiveness in Helping Community College Students to Complete Bachelor's Degrees (Signature Report No. 13). *National Student Clearinghouse Research Center*.
- Shayevich, A., Goldberg, J., & Edson, J. (2008). Performance and retention of transfer engineering students. *2008 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Pittsburgh, PA.
- Sheinberg, B. (2015). An unanticipated outcome of undergraduate research experiences for community college students: Creation of a materials science and engineering educational program. *Materials Research Society*. Vol. 1762.
- Shields, N. & Pietroburgo, J. (2000). Comparing the success of two-year college students and students with other academic backgrounds in a non-traditional engineering program. *2000 American Society for Engineering Education (ASEE) Conference Proceedings*. St. Louis, MO.

- Skurla, C. & Eisenbarth, S. (2013). Scholarships for academic success program: a final report. *2013 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Atlanta, GA.
- Snyder, J. & Cudney, E. (2018). A retention model for community college STEM students. *2018 American Society for Engineering Education (ASEE) Annual Conference Proceedings*. Salt Lake City, UT.
- Snyder, T., de Brey, C., & Dillow, S. (2016). *Digest of Education Statistics 2015*. National Center for Education Statistics. U.S. Department of Education. Washington, DC.
- Starobin, S., Smith, D., & Laanan, F. (2016). Deconstructing the transfer student capital: intersect between cultural and social capital among female transfer students in stem fields. *Community College Journal of Research and Practice*. Vol. 40, No. 12, pp. 1040-1057.
- Sterman, J. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin/McGraw-Hall. Boston, MA.
- Sullivan, M., de Cohen, C., Barna, M., Orr, M., Long, R., & Ohland, M. (2012). Understanding engineering transfer students: demographic characteristics and educational outcomes. *2012 IEEE Frontiers in Education (FIE) Conference Proceedings*. Seattle, WA.
- Tabachnick, B. & Fidell, L. (2013). *Using Multivariate Statistics* (6<sup>th</sup> ed). Boston, MA: Pearson.
- Thomas, J. & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. *BMC Medical Research Methodology*. Vol. 8, No. 45.
- Thorne, S., Jensen, L., Kearney, MH., Noblit, G., & Sandelowski, M. (2004). Qualitative meta-synthesis: reflections on methodological orientation and ideological agenda. *Qualitative Health Research*. Vol. 14, No. 10, pp. 1342-1365.

- Tinto, V. (1993). *Leaving College: Rethinking the Causes and Cures of Student Attrition*. Second Edition. University of Chicago Press.
- Tkacik, P., Lim, J., Tolley, P., & Warren, K. (2012). Gendered socialization during the first semester: contrasting experiences of male and female transfer/non-traditional engineering students. *2012 American Society for Engineering Education (ASEE) Conference Proceedings*. San Antonio, TX.
- Tobolowsky, B. & Cox, B. (2012). Rationalizing neglect: an institutional response to transfer students. *The Journal of Higher Education*. Vol. 83, No. 3, pp. 389-410.
- Townley, G., Katz, J., Wandersman, A., Skiles, B., Schillaci, M., Timmerman, B., & Mousseau, T. (2013). Exploring the role of sense of community in the undergraduate transfer student experience. *Journal of Community Psychology*. Vol. 41, No. 3, pp. 277-290.
- Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of a systematic review. *British Journal of Management*. Vol. 14, pp. 207 – 222.
- U.S. Department of Education, National Center for Education Statistics. (2019). *The Condition of Education 2019 (NCES 2019-144), Undergraduate Retention and Graduation Rates*.
- Virginia Tech Office of Institutional Research (VT OIR). (2017). Retrieved <http://ir.vt.edu/>
- Vroom, V. (1964). *Work and motivation*. Wiley. New York.
- Western Interstate Commission for Higher Education (WICHE). (2016). *Knocking at the College Door: Projections of High School Graduates*, Retrieved <https://static1.squarespace.com/static/57f269e19de4bb8a69b470ae/t/58a73866beba9af53c8e4a/1487353994351/Knocking2016FINALFORWEB-revised021717.pdf>

- Western Interstate Commission for Higher Education (WICHE). (2017). *Knocking at the College Door: Projections of High School Graduates*. Retrieved February 2019 from <https://static1.squarespace.com/static/57f269e19de4bb8a69b470ae/t/58d2eb93bf629a4a3878ef3e/1490217882794/Knocking2016FINALFORWEB-revised021717.pdf>
- Wetzel, L. & Debure, K. (2018). The role of faculty in fostering stem transfer student success. *Journal of College Science Teaching*. Vol. 47, No. 4, pp. 42-46.
- Whang, L., Tawatao, C., Danneker, J., Belanger, J., Edward Weber, S., Garcia, L., & Klaus, A. (2017). Understanding the transfer student experience using design thinking. *Reference Services Review*. Vol. 45, No. 2, pp. 298-313.
- Wilder, J. (1993). A sophomore slump: A complex developmental period that contributes to attrition. *College Student Affairs Journal*. Vol. 12, No. 2, pp. 18-27.
- Yoon Yoon, S. Cortez, M., Imbrie, P., & Reed, T. (2018). A comparative study of student success between first-time-in-college and first-time-transfer engineering students. *International Journal of Engineering Education*. Vol. 34, No. 1, pp. 69-87.
- Zamudio, R. & Davis, S. (2015). From community college to 4-year institutions: Latinas' successful completion of STEM baccalaureate degrees. (Doctoral Dissertation). Retrieved from California State University.
- Zapf, M. (1991). Cross-cultural transitions and wellness: dealing with culture shock. *International Journal for the Advancement of Counseling*. Vol 14, No. 2, pp. 105-119.