The Current State and Future Needs of Systems Engineering Education: A Proposed Curriculum

(Technical Report)

Understanding the Function of a Science, Technology, Engineering and Mathematics Master's Degree

(STS Research Paper)

A Thesis Prospectus Submitted to the

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In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction:

This thesis prospectus will be divided into two primary components: the Technical portion, regarding the design and creation of the University of Virginia Northern Virginia campus Accelerated Masters Program in Systems Engineering, and the Science, Technology, and Society portion, regarding the function and performance of STEM higher education degrees in the labor force. While higher education is continually a hot topic debate in the United States, it is critical to understand the underlying trends and associated employment opportunities in order to develop the most optimal, valuable, and effective advanced degree program. With the cost of tuition rising, this paper intends to provide insight into how these degrees provide benefits worthy of the growing cost to participate.

Technical Description:

In May of 2023, the University of Virginia will launch their new Accelerated Masters in Systems Engineering program at the Northern Virginia campus. While the previous AMP program ran for more than 20 years, the COVID-19 pandemic provided an opportunity to reevaluate and improve upon the existing frameworks to provide a truly unique and valuable higher education experience. The inaugural class will be taking part in a newly designed course and curriculum that will provide students with technical skills and a signal to employers of their proficiency in systems thinking and application. Working with Professor and Associate Chair William Scherer, our team is tasked with helping the new director, Professor Matt Burkett, evaluate the existing masters program market and develop the curriculum from the ground up.

Initial Market Analysis

In an effort to understand the broader landscape of Systems masters degree programs, particularly in the D.C., Maryland, and Virginia area, the team has compiled market research materials encompassing a number of critical consideration metrics such as tuition per credit hour, course load, course structure, and several others. To provide a unique value proposition to prospective students, the team has recognized that an understanding of the market environment and alternatives will allow the UVA Northern Virginia program to provide differentiating factors that enhance the experience of students and their potential post graduation prospects.

Course Design and Structure Consideration

Utilizing framework templates such as the one provided in figure 1, the team has generated multiple potential approaches to the program, each providing a special value proposition to students that represents a unique educational experience.

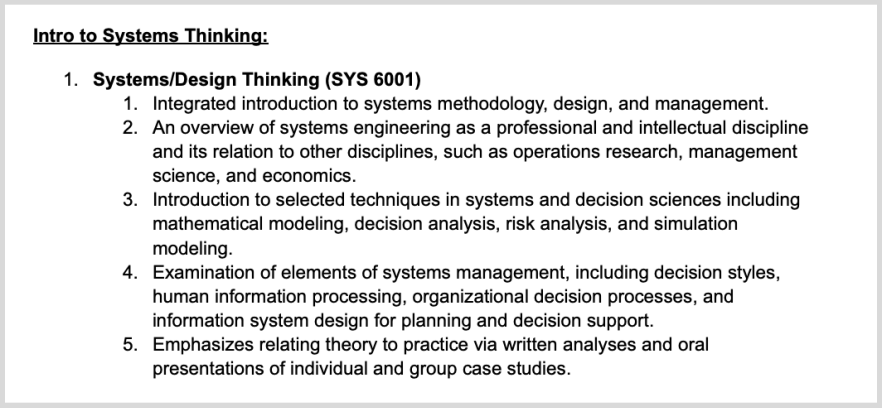
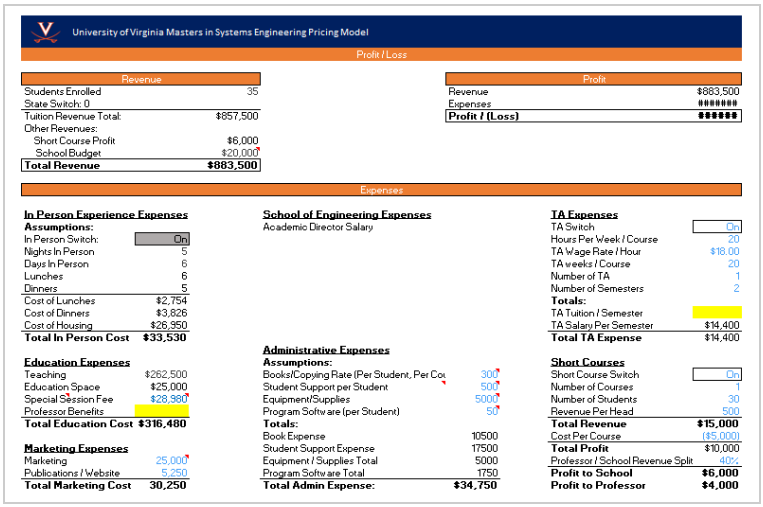


Figure 1: *Course Pitch Template*

Understanding the design goals and constraints of the project has allowed the team to address the ten course structure with several outcomes in mind, such as student enrollment, skill development, and post graduation performance. While considering the potential prerequisites, a large portion of consideration is given to the student demographic and archetype that the program should be designed to capture and interest. Decisions such as acceptance metrics determine the necessary background of students, and course difficulty constraints needed.

Curriculum Budgeting Consideration

As both advocates for the financial success of the school and the cost constraints and capabilities of potential students, course budgeting and resource allocation represents a large factor in determining curriculum viability. To allow the budgeting consideration to be both dynamic and flexible to several assumptions, the team has generated a deterministic budget model to project potential profit or loss under certain situations. As seen in figure 2, the budgeting model allows the project profit to be flexed under considerations such as number of courses, students enrolled and tuition cost among several others.



University of Virginia Masters in Systems Engineering Pricing Model

Profit / Loss

Revenue	
Students Enrolled	35
State Switch: 0	
Tuition Revenue Total:	$857,500
Other Revenues:	
Short Course Profit	$6,000
School Budget	$20,000
Total Revenue	**$883,500**

Profit	
Revenue	$883,500
Expenses	########
Profit / (Loss)	######

Expenses

In Person Experience Expenses	
Assumptions:	
In Person Switch:	On
Nights In Person	5
Days In Person	6
Lunches	6
Dinners	5
Cost of Lunches	$2,754
Cost of Dinners	$3,826
Cost of Housing	$26,950
Total In Person Cost	**$33,530**

Education Expenses	
Teaching	$262,500
Education Space	$25,000
Special Session Fee	$28,980
Professor Benefits	
Total Education Cost	**$316,480**

Marketing Expenses	
Marketing	25,000
Publications / Website	5,250
Total Marketing Cost	**30,250**

School of Engineering Expenses	
Academic Director Salary	

Administrative Expenses		
Assumptions:		
Books/Copying Rate (Per Student, Per Co	300	
Student Support per Student	500	
Equipment/Supplies	5000	
Program Software (per Student)	50	
Totals:		
Book Expense	10500	
Student Support Expense	17500	
Equipment / Supplies Total	5000	
Program Software Total	1750	
Total Admin Expense:		**$34,750**

TA Expenses	
TA Switch	On
Hours Per Week / Course	20
TA Wage Rate / Hour	$18.00
TA weeks / Course	20
Number of TA	1
Number of Semesters	2
Totals:	
TA Tuition / Semester	
TA Salary Per Semester	$14,400
Total TA Expense	$14,400

Short Courses	
Short Course Switch	On
Number of Courses	1
Number of Students	30
Revenue Per Head	500
Total Revenue	**$15,000**
Cost Per Course	($5,000)
Total Profit	$10,000
Professor / School Revenue Split	40%
Profit to School	**$6,000**
Profit to Professor	**$4,000**

Figure 2: *Budgeting Model P&L Tab*

Future Considerations

In the coming months, the team will focus primarily on the definition and finalization of the program structure and schedule. With that completed, the focus of the project will pivot to generating marketing materials and working with teachers to develop fully developed course curriculums. In an effort to capture technically minded individuals with an aptitude and career interest in management, the program has narrowed in on a potential curriculum consisting of entrepreneurship courses along with semi-advanced technical skill building to provide students with the tools necessary to oversee highly technical projects.

STS Discussion:

With both STEM degrees and Master's degrees becoming more popular, the question remains regarding both their function and utility in the labor force. While an undergraduate degree is, for the most part, viewed as essential to breaking into the top tier of earners in America, advanced education is considered much more situational. In 2018, 733,445 STEM degrees were conferred by post secondary institutions. Despite the fact that more women are seeking these degrees, men represent approximately two thirds of those degrees conferred. Similarly, the number of degrees conferred to white individuals is larger than the number of degrees conferred to all other races, combined. Furthermore, STEM subjects are far less frequently pursued on the graduate level, for, unlike the education and business fields, the degree is not commonly seen as a critical stepping stone to furthered promotion and advancement. As of 2019, natural sciences and mathematics only accounted for 4% of Masters degrees conferred, with the slightly more applied computer sciences and engineering disciplines only accounting for 12% (USAFacts). As such, the question remains what is the function

of these degrees? Why are students willing to take part in the growing student debt crisis for these degrees, and where is the underlying motivation reflected in the labor force?

Understanding STEM Field Requirements

As stated by the Pew Research center, "among college educated workers, one-in-three majored in a STEM field..but only about half of those with college training in a STEM field are currently employed in a STEM Job." Pew recognizes this statistic as a product of the advanced degree requirements commonly considered essential in the field. While only 12% of the labor force in non-STEM fields have a postgrad degree, 29% of STEM employed graduates hold a postgraduate degree as of 2016. Furthermore, when compared to all employment, STEM professionals are almost twice as likely to work for a non-for-profit and almost half as likely to be self employed (PEW). With this in mind, how does self employment manifest? Is this representative of a lack of mobility within the workforce, or an underdeveloped market for freelance work? Understanding the career ladder and professional advancement structure of the industry is critically important in understanding motivations for students pursuing masters, and provides an interesting challenge in understanding post graduate opportunities.

Understanding Advanced Higher Education

The public perception around higher education has taken several forms throughout the last century. While once a symbol of privilege and elitism for the upper class, both undergraduate and advanced degrees have experienced a slow democratization that remains changing today. While the burden of student debt maintains a high barrier for many, the real reason a degree is valuable may be more complex than simply its payoff. In the pre-Reagan era, degrees gradually shifted away from representing intellectual exploration, and as such, an increasing number of Universities have shifted to emphasizing job training, paring down courses that are less applicable to skills that provide value to the labor market. As Reagan explained, "intellectual luxuries," like courses unrelated to a potential career, should be seen as a meaningless expense to both the school system and to the time of students (The Chronicle). However, is this simplification of education truly improving the experience of students? Arguably more importantly, does it really impact their career prospects?

Defining Value

The conversation around educational value can come in many forms and contexts. While the economic perspective may be the most discussed in news headlines, is there an inherent value to educational experiences beyond their economic payoffs? Does education represent a component of a diverse lifestyle and an extension of individual passions? Through this research, I hope to include a conversation around education as beneficial from a holistic development perspective, as well as the economic opportunities it provides.

Research and Frameworks

While working on this thesis, I intend to analyze both statistical information provided by reputable sources such as the US Department of Commerce or Labor and similar government bodies, research centers, and published statistical reports, as well as theoretical papers discussing the function of education. In the coming months, a large portion of the work will reside in the research and knowledge development, in turn informing my eventual conclusions. As such, I intend to rely heavily on both history and philosophy to provide a holistic representation of the answers to my research questions. Furthermore, I intend to utilize heavily the Actor-Network Theory Framework to demonstrate the critical actors underlying the higher education and labor system and their relationship to one another.

Key Texts

In the preceding sections, I have referenced a couple of sources that have been of distinct value to my preliminary research. As such, I intend to rely on a couple texts heavily in my attempt to demonstrate my conclusions from research and discuss my findings. While these are what I believe to be most important from my initial understanding of the topic, I believe that several more pieces of literature will become equally important as well.

USAFacts has published statistics pulled directly from the National Center for Education Statistics, and I have heavily depended upon their compiled statistics regarding Masters Degrees and the STEM field. This is extremely valuable to my research as quantitative metrics that display overarching trends are necessary in understanding any industry. Understanding all facets of advanced degrees, from relevant social groups to key outcomes, is essential to my discussion, and I have found myself referencing this site multiple times throughout my initial discovery period.

In regard to more theoretical aspects of my paper, I intend to utilize Theodore Porter's book, *Trust in Numbers,* to discuss the complex underlying issues with the way in which we evaluate education from a quantitative point of view. As Porter explains how the impact of expert opinions and objectivity affects society, I believe this is highly relevant to the field of advanced education. From the beginning of my early research, I have noticed how much quantitative data exists on the space, and the extent to which this data impacts the decision making of higher education institutions. While I myself intend to use numerical and quantitative evidence a great deal in my writing as well, I believe that a discussion of the potential shortcomings of this method is important to the overarching research question.

Following up on Porter's book, I think that Cathy O'Neils book, *Weapons of Math Destruction*, will be similarly useful to my theoretical discussion around how we use quantitative methods to determine and assess the outcomes of education. As O'Neil explains, the interpretation of advanced mathematics, and the decisions made in the effort to provide the most insight from data and mathematics, is effectively never safe from implicit biases. With her distinct discussion around the US News and World Report University ranking system, I think that both her directly education related content and even her conclusions in general are of great value to my project.

Finally, I also intend to rely heavily on a collection of excerpts called *Skills for Future Workers*, which discuss multiple perspectives on the influence of AI on the workforce. I think that this will be extremely useful in demonstrating any argument around the function of education as a catalyst to skill development, especially in technical fields such as STEM. In particular, the excerpt from Arthur Graesser is of interest as it discusses the value of collaborative problem solving, something that is heavily associated with engineering and technical graduates. I believe that this will be specifically valuable in a discussion around the future of the workforce as it relates to educational requirements, and believe that the multiple and mixed opinions from this piece will add an interesting dimension to the discussion.

Conclusion:

In summary, the goal of this report is to both develop a truly valuable Masters experience for students and demonstrate an understanding of the function of higher education and its application to the STEM field. From preliminary research, it is apparent that much of the value provided in higher education comes down to

simple economics. While cost and career prospects with the degree in hand has perhaps become the primary concern, the question remains: is there an approach to curriculum design that allows students to reevaluate their motivation for education once enrolled?

References:

Average Salary by Education Level: Value of a College Degree. (n.d.). Retrieved October 9, 2022, from https://www.northeastern.edu/bachelors-completion/news/average-salary-by-education-level/.

Byars, Winston, & Angela (2014). *Toward a Framework for Multicultural STEM-Focused Career Interventions.* Career Development Quarterly 62 (4): 340–57. Retrieved December 12, 2022, from doi:10.1002/j.2161-0045.2014.00087.x.

Funk, C., & Parker, K. (2018, January 9). 1. Diversity in the STEM Workforce Varies Widely across Jobs. *Pew Research Center's Social & Demographic Trends Project*. https://www.pewresearch.org/social-trends/2018/01/09/diversity-in-the-stem-workforce-varies-widely-across-jobs/.

Graesser, A. C., Walter, S. C., Schokker, T., & Goroff, D. L. (2019). *Skills For Future Workers.* Issues in Science and Technology, vol. 35, no. 2 pp. 10–13. Retrieved December 12, 2022, from *JSTOR*, https://www.jstor.org/stable/26948977.

Hess, A. J. (n.d.). *The master's degrees that give the biggest salary boost—up to 87% more money.* CNBC. Retrieved October 9, 2022, from https://www.cnbc.com/2021/09/24/the-masters-degrees-that-give-the-biggest-salary-boostup-to-87percent.html.

O'Neil, C. (2017). *Weapons of math destruction : how big data increases inequality and threatens democracy*. Crown Publishing. Retrieved December 12, 2022, from https://collab.its.virginia.edu/access/content/group/2218fe68-265c-4891-91fc-c1975742a066/Course%20Readings/Cathy%20O'Neil-Weapons%20of%20Math%20Destruction_%20How%20Big%20Data%20Increases%20Inequality%20and%20Threatens%20Democrac%20_2016_.pdf.

Porter, T. M. (1995). *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton University Press. Retrieved December 12, 2022, from https://collab.its.virginia.edu/access/content/group/2218fe68-265c-4891-91fc-c1975742a066/Course%20Readings/Theodore%20M.%20Porter-Trust%20in%20Numbers-Princeton%20University%20Press%20_1995_.pdf.

STEM degrees conferred by postsecondary institutions. (n.d.). USAFacts. Retrieved October 9, 2022, from https://usafacts.org/data/topics/people-society/education/higher-education/stem-degrees-conferred-postsecondary-institutions/.

The Day the Purpose of College Changed. (n.d.). Retrieved October 12, 2022, from https://www.chronicle.com/article/the-day-the-purpose-of-college-changed/.

These are the degrees that will earn you the most money when you graduate - and the ones that won't. (n.d.). World Economic Forum. Retrieved October 9, 2022, from https://www.weforum.org/agenda/2021/10/stem-degrees-most-valuable/.

USAFacts. (n.d.). *Master's degrees conferred.* USAFacts. Retrieved October 9, 2022 from https://usafacts.org/data/topics/people-society/education/higher-education/masters-degrees/.

What's the purpose of college: A job or an education? (n.d.). *Washington Post.* Retrieved October 12, 2022, from https://www.washingtonpost.com/news/grade-point/wp/2015/02/02/whats-the-purpose-of-college-a-job-or-an-education/.