Science, Technology, Engineering, and Mathematics (STEM) Career Attractiveness System Dynamics Modeling

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Abstract

A system dynamics model was developed in response to the apparent decline in STEM candidates in the United States and a pending shortage. The model explores the attractiveness of STEM and STEM careers focusing on employers and the workforce. Policies such as boosting STEM literacy, lifting the H-1B visa cap, limiting the offshoring of jobs, and maintaining training are explored as possible solutions.

The system is complex, with many feedbacks and long time delays, so solutions that focus on a single point of the system are not effective and cannot solve the problem. A deeper understanding of parts of the system that have not been explored to date is necessary to find a workable solution.
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CONTENTS

1. Introduction ................................................................................................................. 9
2. Model Description .................................................................................................... 11
3. Model Comparison .................................................................................................... 13
4. Results ....................................................................................................................... 15
   4.1. Base run ............................................................................................................ 15
   4.2. Policy Option Implementations ........................................................................ 26
       4.2.1. Lift H-1B visa cap..................................................................................... 26
       4.2.2. Boost literacy ............................................................................................ 28
       4.2.3. Curb offshoring of jobs............................................................................. 31
       4.2.4. Maintain training....................................................................................... 32
   4.3. Policy Comparisons .......................................................................................... 33
   4.4. Analysis............................................................................................................. 44
5. Conclusions............................................................................................................... 47
6. References ................................................................................................................. 49
Appendix A: Model views and Equations ....................................................................... 51

FIGURES

Figure 1: STEM stakeholder groups ................................................................................ 10
Figure 2: Attractiveness of STEM ................................................................................... 11
Figure 3: Pressure to economize .................................................................................... 12
Figure 4: Sectors and model areas of focus .................................................................... 14
Figure 5: K through 12 STEM resource adequacy: base run ........................................... 15
Figure 6: STEM literacy and STEM degree interest: base run ........................................ 16
Figure 7: STEM college enrollments and graduation: base run ....................................... 16
Figure 8: Entry level labor: base run .............................................................................. 17
Figure 9: STEM graduates and the domestic labor market causal diagram ...................... 18
Figure 10: Importation of foreign labor: base run ......................................................... 18
Figure 11: Importation of foreign labor causal diagram ................................................... 19
Figure 12: Entry level worker training: base run ............................................................. 20
Figure 13: Entry level revolving door: base run .............................................................. 20
Figure 14: Continuing education and skills lifetime causal diagram .............................. 21
Figure 15: Offshoring: base run ..................................................................................... 22
Figure 16: Offshoring causal diagram .......................................................................... 23
Figure 17: Deteriorating skills: base run ....................................................................... 24
Figure 18: Graduate school: base run ......................................................................... 24
Figure 19: Higher level jobs: base run ......................................................................... 25
Figure 20: Attractiveness of STEM careers: base run ................................................. 26
Figure 21: Importation of foreign labor: cap lifted ........................................................... 27
Figure 22: H-1B visa petitions: cap lifted ..................................................................... 27
Figure 23: Entry level labor deficit: cap lifted ............................................................... 28
Figure 24: STEM resource adequacy: boost literacy ....................................................... 29
Figure 25: STEM literacy at exit: boost literacy .............................................................. 29
Figure 26: Graduates considering STEM degrees: boost literacy ................................... 30
Figure 27: Desired offshoring: curb offshoring ............................................................ 31
Figure 28: Entry level domestic jobs: curb offshoring .................................................. 32
Figure 29: Entry level continuing education: maintain training .................................... 33
Figure 30: Higher level continuing education: maintain training .................................. 33
Figure 31: High school graduates considering STEM degrees ....................................... 34
Figure 32: Attractiveness of STEM careers ................................................................. 35
Figure 33: College graduates ....................................................................................... 36
Figure 34: Entry level labor deficit ................................................................................ 37
Figure 35: Average annual entry level salary ............................................................... 37
Figure 36: Higher level labor surplus .......................................................................... 38
Figure 37: Average annual higher level salary ............................................................. 38
Figure 38: Average time to fill entry level vacancies .................................................... 39
Figure 39: Average time to fill higher level vacancies .................................................. 40
Figure 40: H-1B visa petitions ..................................................................................... 40
Figure 41: Foreign labor ............................................................................................... 41
Figure 42: Entry level worker annual continuing education hours ............................... 42
Figure 43: Entry level vacancies .................................................................................. 42
Figure 44: Higher level worker annual continuing education hours ............................ 43
Figure 45: Higher level yearly vacancies ..................................................................... 43
Figure 46: Yearly offshored jobs .................................................................................. 44
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE</td>
<td>Department of Energy</td>
</tr>
<tr>
<td>SNL</td>
<td>Sandia National Laboratories</td>
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<tr>
<td>STEM</td>
<td>Science, technology, engineering, and mathematics</td>
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</tbody>
</table>
1. INTRODUCTION

This work was prompted by the National Academies’ report, “Rising Above the Gathering Storm,” and follow-on discussions and workshops that highlight concerns regarding the decline and potential shortage of STEM candidates in the US educational system. The concern is that the decline is likely to result in a shortage of a STEM educated domestic labor force and a loss of US competitiveness in STEM-related fields.

The system that produces a STEM educated workforce consists of local and federal government, K-12, higher educations, the STEM workforce and employers as large stakeholder groups as shown in Figure 1. The goal of all of these stakeholders is to produce people educated in STEM that enter and stay in the STEM workforce. Prior modeling efforts of this system focused heavily on the K-12 portion of the system (see [1] and [2]). In order to gain a better understanding of the system as a whole, the work described in this document focused on the STEM workforce and employers, with a lesser focus on higher education through the idea of the attractiveness of STEM as a career. The other stakeholders are included, but not modeled in detail.

Many different reasons are cited as causing the shortage. There are also competing viewpoints on whether there is a shortage. Business and academia claim that there is an inadequate supply of STEM workers, while STEM workers [3] and economic indicators [4] disagree.

The work described here explores the system through the attractiveness of STEM and its influencing factors. This look at the system focuses heavily on the STEM workforce and employers sectors and examines the possible causes of the disparate viewpoints on whether there is a shortage, potential causes, and potential solutions.

The following sections of the report describe the model, compare it to other models on this topic, discuss the model baseline, discuss several policy options, and finally examine results and future direction.
Figure 1: STEM stakeholder groups
2. MODEL DESCRIPTION

The model was designed to capture the movement of students through the educational system and into the workforce, focusing primarily on the factors that cause students to choose STEM as a degree field and subsequently continue on into a career in STEM. The model also explores employers and job availability from the perspective of the economics of the firm, including the pressure to cut costs to be globally competitive by offshoring jobs, and cutting funding to continuing education initiatives. Firms in the model also have the ability to hire foreign workers through the H-1B visa program as a way to augment the size of the workforce.

Figure 2 shows the factors that were modeled as feeding into the attractiveness of STEM and how that variable affects both students that choose STEM as a degree field and those that choose to actually enter the workforce.

From the perspective of the workforce, the model looks primarily at wages and the risk perception of STEM as a career as factors that influence attractiveness. While many other factors may play into whether STEM is considered attractive, these were chosen as the factors to model because it was possible to model them using available information and to focus on the easily observable indicators. The risk perception of the career has to
do with job availability and job stability – e.g. can a person with a STEM degree get a job? Will that person be likely to still have a job in a few years?

The workforce in the model is broken up into both entry level and higher level workers. Similar factors affect both of these pools of labor. Their differences will be discussed in detail in the model results section.

Figure 3 shows the factors included in the model that affect job availability and the efforts of firms to economize to make themselves globally competitive. Wages directly affect operating costs of companies. Thus when wages begin to rise, as they would in a shortage of available labor, firms have several options to cut costs and economize. Those options range from cutting the amount spent on continuing education to offshoring of jobs, both of which are captured in the model. The decision to economize by cutting the amount of continuing education available links back to the attractiveness of STEM as shown in Figure 2 by increasing the risk perception. This in turn reduces the number of people in the workforce, reducing the adequacy of the labor pool and triggering the desire to hire foreign labor.

Figure 3: Pressure to economize
3. MODEL COMPARISON

Several different groups have developed system dynamics models of the STEM system each focusing on different areas of the system. Models developed by Raytheon [1] and Sturtevant (Boeing/MIT model) [2] focus heavily on the K-12 portion of the system and examine teacher salary and quality and quantity of STEM teachers.

Figure 4 shows the different sectors that comprise the system that results in skilled people in the STEM workforce and where some of the modeling efforts have focused. The sectors are: K-12 education, higher education, STEM workforce, local government, federal government, and employers.

Grey depicts sectors that are touched on, green sectors have been covered in some detail, black sectors have not been covered, and blue sectors are covered in the current work. The red item -- “attractiveness of STEM careers” -- is the focus of the current model. In order to explore the attractiveness of STEM careers factors that affect the STEM workforce, employers, and the federal government need to be examined in more detail than has been done in past models.

The Boeing/MIT model and the Raytheon model described in [1] focus heavily on K-12 education and teacher salary in comparison with the salary for STEM educated people in industry. The Raytheon model touches on higher education and the entry of the STEM literate into the workforce, but does not explore those segments in detail. The current work was focused on areas not already covered in detail by these prior models around the notion of the attractiveness of STEM careers. Focusing on attractiveness led the model development to explore the STEM workforce, employers, federal government visa policies in detail and touch on higher education, and not explore local government or K-12 education except as an input source for the model.

Since the models focus on distinctly different areas, there is no good basis for comparison between them. However, future work could allow for the linking of the models together to better explore the effects of various policy options and capture more segments of the system in detail in one model.
Figure 4: Sectors and model areas of focus
4. RESULTS

The model was run under a baseline scenario and with several policy options. The baseline scenario is a decline of STEM literacy showing the effects as this decline propagates through the system.

4.1. Base run

The base run assumes a steady small decline in K-12 STEM literacy. It does not attempt to explore the cause of the decline, this has been done in the work described in [1] and [2]. The decline is implemented here as a decline in K-12 STEM resource adequacy that stops in 2008 as shown in Figure 5.

Despite the decline halting in 2008, it takes five to ten years for STEM literacy and the number of high school graduates considering STEM degrees to level off as shown in Figure 6.
The declining rate of high school graduates interested in STEM degrees results in declining college enrollment, attendance, and graduation in STEM fields as shown in Figure 7. After 2008 this trend is more pronounced due to other portions of the model which will be discussed later in this section.

Figure 6: STEM literacy and STEM degree interest: base run

Figure 7: STEM college enrollments and graduation: base run
Fewer college graduates in STEM leads to fewer people entering the STEM labor force. This results in the labor deficit for entry level positions seen in Figure 8. As a result, it takes longer to fill job vacancies, and entry-level wages increase:

Figure 8: Entry level labor: base run

Figure 9 shows how the decline in STEM literacy leads to a decrease in the STEM labor pool. In the figure “+” signs represent variables that affect one another in the same direction, for example as the number of STEM college graduates goes up, so does the STEM labor pool. Alternatively, as the number of STEM college graduates goes down so does the STEM labor pool. Relationships denoted by a “−” mean that they move in opposite directions. A decrease in labor adequacy causes an increase in wages to attempt to attract more workers, while an increase in labor adequacy would cause a decrease in wages. The link from labor adequacy to wages trigger other parts in the system that cause the decline in STEM college graduates from the declining literacy to be more pronounced. These will be described later in this section.
An additional option available to employers to keep wages low when labor adequacy falls is the importation of foreign workers under H-1B visas. Employers attempt to fill the labor gap with foreign workers as shown in Figure 10 but the H-1B visa cap, set at the 65,000 limit shown in the figure, will limit their ability to do so:
Figure 11: Importation of foreign labor causal diagram

Figure 11 adds the variables related to the importation of foreign labor into the loop diagram and depicts how that affects the availability of labor. As the number of domestic STEM graduates falls, so does the size of labor pool, which would cause wages to increase. However, as the size of the labor pool falls, the desire to hire foreign labor increases which increases the size of the labor pool, balancing the need to raise wages.

In a very competitive, global economy, employers cannot easily afford to absorb the entry-level wage increases, thus they turn to foreign labor and other efforts to economize to sustain their profit without increasing prices. One way to reduce operating costs is to cut back on corporate-sponsored training as shown in Figure 12. The model assumes that the maximum amount of corporate provided training is 80 hours per year with an average of 40 hours per worker per year.
Reduced training shortens the lifetime of entry-level workers’ STEM skills, particularly in a fast-changing technological environment. Without retraining employees, employers are implicitly opting for replacing the workforce more frequently with a fresh batch of college graduates with up-to-date skills. This results in a “revolving door” of entry level positions and lower perceived STEM career stability as shown in Figure 13.

Figure 12: Entry level worker training: base run

Figure 13: Entry level revolving door: base run
Figure 14: Continuing education and skills lifetime causal diagram

Figure 14 adds the variables relating to continuing education to the diagram. As wages go up, pressure to economize also goes up and the willingness to allocate funds to corporate sponsored training goes down. This causes the length of lifetime of skills to go down along with the people eligible for jobs and the size of the labor pool. As the skills lifetime of current workers deteriorate, their length of stay in the job goes down, thus they are replaced with new entry level workers.

Employers can also offshore entry level jobs to places where people with basic skills are more affordable in response to rising wages. As a result, the pool of domestic jobs available at the entry level decreases as shown in Figure 15.
Figure 16 adds the variables relating to offshoring of jobs to the diagram. As mentioned previously, as wages go up, pressure to economize also goes up. An additional method of economizing available to corporations is the offshoring of entry level jobs. Offshoring of jobs becomes more attractive as domestic wages increase. At a particular threshold it becomes more economical to offshore a number of jobs. This causes the necessary size of the domestic labor pool to decrease and helps hold wages down.
The factors as discussed to this point apply to entry level jobs. Similar effects occur in higher level jobs. As the rate of people with basic degrees becoming obsolete rises; many choose to retrain themselves by joining a higher-level, graduate program. As a result, the number of people with basic degrees eligible for entry-level positions falls drastically as shown in Figure 17.
As those deciding to stay in the STEM field choose to pursue graduate programs to maintain or augment their skills, enrollment, attendance and graduation from higher-level programs rises. This creates an increase in the supply of people with advanced degrees as shown in Figure 18. This increase is not sustainable, due to the fact that the number of people with undergraduate degrees is declining.
Increased supply of higher-level workers compared to higher level jobs results in a surplus of higher-level labor as shown in Figure 19. This leads to declining higher-level wages which eventually begin to increase due to the overall decline in college graduates.

The overall attractiveness of the STEM field is a composite measure made up of wages, the likelihood of getting an entry level job, offshoring, promotion potential, and career potential. In the base run, initially the attractiveness of STEM rises due to increasing entry level wages and a high likelihood of getting a first job. As shown in Figure 20, eventually attractiveness falls because those factors are not sustainable due to declining tenure in entry level jobs and loss of domestic jobs due to offshoring.
4.2. Policy Option Implementations

The model allows for the exploration of several different proposed policy solutions. Several were explored as part of the study and are compared to the base run. This section describes the implementation of those policies in the model. The policy options include lifting of the H-1B visa cap, boosting STEM literacy, curbing the offshoring of jobs, and maintaining training.

4.2.1. Lift H-1B visa cap

This run assumes that there never was a visa cap. Therefore, the entry-level labor gap can be covered via importation of labor as shown in Figure 21. Normally, policy changes are enacted in the current or subsequent years. However, since the base run shows the limiting effect of the cap happening between 2001 and 2009 the effects of removing the cap are more easily seen if it is not included initially. The cap is a temporary limiting factor and could happen at any point, thus eliminating it altogether can show whether the cap itself is beneficial or harmful to the pool of STEM candidates.
An immediate observation resulting from the elimination of the cap is that the number of work visas petitioned is significantly reduced as shown in Figure 22. This occurs because lifting the cap allows the gap to be closed faster and does not allow the gap to continue to widen as shown in Figure 23.
4.2.2. Boost literacy

This policy entails raising the level of literacy in K-12 education to its 1983 value. To achieve this result, an immediate increase in STEM resource adequacy is used to correct for the steady deterioration portrayed in the base run scenario. This increase is shown in Figure 24 and results in the increase in average STEM literacy at exit of K through 12 shown in Figure 25.

It takes 10-15 years to achieve the intended objective of the policy, because it takes 12 years to move an entire cohort of children through basic education at the new resource level. Children who are partway through the process cannot “catch up” due to existing deficiencies --unless additional resources are put in place to help them do so. This policy corrects for the “assumed scenario” of what is causing the STEM problem: deterioration in science and math education originating in basic education.
As a result, the number of high-school graduates considering STEM degrees rises to its previous level as shown in Figure 26, but not quickly enough to fix the short-term STEM problem. The number of people considering STEM degrees does not return to pre-decline levels until 15 years after resource adequacy is boosted to its pre-decline level.
Figure 26: Graduates considering STEM degrees: boost literacy
4.2.3. **Curb offshoring of jobs**

This policy does not eliminate offshoring of jobs, but curbs it significantly ("willingness to offshore EL jobs is changed from 1 to 0.1). Similar to the implementation of the policy to lift the visa cap, this policy is in place throughout the simulation to better visualize its full potential effect. The effect this policy has on the number of jobs to offshore is shown in Figure 27.

![Figure 27: Desired offshoring: curb offshoring](image)

While the rate of jobs being offshored is significantly reduced, this rate is sustained over a longer period of time and, eventually, is greater than in the base run. Thus, in the very long run, curbing offshoring will tend towards a similar number of accumulated job losses as shown in Figure 28.
4.2.4. Maintain training

This policy maintains the amount of “corporate-sponsored” continuing education throughout the simulation for both entry-level and higher-level workers. In other words, it guarantees that employers will not curb training to economize on operating costs whenever labor costs increase (nor increase training if wages fall and there is some surplus money in the operating budget).  

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1 The policy implies the existence of a financial mechanism to create and maintain this incentive, such as a governmental subsidy or tax benefit, just as the policy of curbing offshoring of jobs would also require some sort of incentive mechanism to achieve its intended goal.
4.3. Policy Comparisons

This section compares the effects the various policies have on key variables of interest.
Boosting STEM literacy in basic education is the only policy that will reestablish the original level of interest in STEM degrees and careers by high-school graduates as shown in Figure 31. Students considering STEM degrees in the model are all students with adequate levels of STEM literacy. Since the model has no feedback mechanisms into STEM literacy, no other policy can have as dramatic an effect, since the other policies can only affect people that have the necessary levels of STEM literacy.

If the attractiveness of the STEM field could alter the students’ literacy or ability to excel in science and math K-12 education then, the feedback into the K through 12 portion of the model could be closed and other policies could change the number of STEM eligible graduates. However, attractiveness does not have this affect and only “curbing offshoring” and “maintaining training” are able to enhance the attractiveness of the STEM field/career as shown in Figure 32.

If the feedback existed, an isolated effort to increase STEM literacy in K-12 education would likely be ineffective, because it does not address the problem of “perceived unattractiveness” of this field, due to factors explored further below. Students would be better equipped for STEM careers but not be inclined to pursue them.

Successful curbing of offshoring of jobs quickly increases the attractiveness of the STEM career, whereas sustained corporate-sponsored continuing education increases it over the longer time horizon:
Curbing the process of offshoring jobs alone is not a sustainable strategy to maintain the attractiveness of the field, whereas continuing education does sustain gains in perceived attractiveness.

Lifting the H-1B visa cap does little to improve attractiveness as compared to the base run. In the short term, it makes the field even less attractive to the pool of high-school graduates deciding on what degrees to apply for in college.

Combining the number of high school graduates considering STEM degrees with the attractiveness of the field results in the number of college graduates in STEM fields shown in Figure 33.

Figure 32: Attractiveness of STEM careers
None of the policies, used in isolation, can recoup and sustain gains in the falling graduation rates. Due to the “attractiveness” factor, curbing the offshoring of jobs does well in the short term, while maintaining training reverses the trend and sustains the level of college output in the labor market, albeit at a lower level.

For entry-level positions and workers, the policy to maintain training avoids a large labor deficit, while sustaining marginal wage increases as shown in Figure 34 and Figure 35. The only other policy that stands out from the base run is curbing the offshoring of jobs which boosts entry-level wages.
Similarly, for higher-level positions and workers, the policy to maintain a fixed amount of corporate-sponsored training avoids a labor surplus, while sustaining marginal wage increases (as opposed to observed losses in the base run) as shown in Figure 36 and Figure 37.
Again, the policy curbing the off shoring of jobs stands out from the base run, but now with significant wage losses. For higher-level positions and workers, the policy boosting STEM literacy in K-12 education also fares better than the base run, although also with wage losses.

Figure 36: Higher level labor surplus

Figure 37: Average annual higher level salary
For employers, while wage increases for entry-level workers could be offset with wage decreases for higher-level workers, difficulties in filling entry-level vacancies would remain a problem with the policy of curbing the offshoring of jobs. As shown in Figure 38, the time to fill entry level vacancies rises and remains at a higher level than with other policies.

![Figure 38: Average time to fill entry level vacancies](image)

Keeping jobs here and protecting the U.S. labor force would likely result in a two-fold increase in hiring delays for entry-level positions. Due to a labor surplus of people with advanced skills, “boosting literacy” and “curbed offshoring,” both, reduce the average time to fill higher-level vacancies, relative to the base run as shown in Figure 39.
As previously noted, lifting the H-1B cap significantly reduces the peak number of work visas petitioned by U.S. companies. The policy to curb the offshoring of jobs, however, would increase it almost two fold as shown in Figure 40.
Continued training could be effective in reducing the need for foreign workers, and in avoiding a “rush” for H-1B visas. The policy to curb the offshoring of jobs would likely guarantee a continued inflow of foreign workers limited only by the existence of a cap as shown in Figure 41.

![Figure 41: Foreign labor](image)

Domestic wage increases for entry level workers, without a corporate commitment to (or government subsidy of) continuing education, are likely to lead to frequent replacement of the entry level workforce with recent college graduates to obtain new skills. This will allow employers to reallocate training dollars towards paying higher wages. As a result, the entry-level “revolving door” will spin faster, as observed in the higher number of job openings to be filled as shown in Figure 42 and Figure 43.
For higher-level workers, the opposite is observed due to the surplus of advanced-skills labor and lower wages. The amount of corporate-sponsored training could actually increase as shown in Figure 44. Employers would tend to keep these workers for longer and, thus, reduce the vacancy creation rate as shown in Figure 45.
Continuing education helps increase and sustain the attractiveness of the STEM field, in spite of decreased levels of math and science literacy in K through 12. An adequate supply of workers compared to jobs available reduces the need to import labor or to offshore jobs, particularly by avoiding inflationary wage gains. As a result, the policy that maintains training seems to fare...
better in keeping jobs here than the policy curbing the offshoring of jobs does as shown in Figure 46.

![Figure 46: Yearly offshored jobs](image)

4.4. Analysis

The need to import skilled labor and offshoring of jobs are symptoms of inadequacy in the labor force, whether in sheer numbers or in skill sets. Fixing the symptoms resulting from these inadequacies may produce favorable results initially, those results are not sustainable in the long term. In many cases they are likely to exacerbate the root problem – the U.S. is losing its relative advantage in STEM fields, both in terms of jobs and innovative minds, to the countries attracting those jobs and cultivating these minds.

Retraining and retooling the workforce, irrespective of cost, may be a strategy to deal with the STEM drainage. In order to avoid losing competitiveness in the global market-place, particularly in the face of lower wages abroad, employers will need to receive subsidies or other financial incentives to sustain the level of training required for their workforce. Those who are, temporarily out of employment should also have affordable access to retraining, particularly when technology and necessary knowledge is changing at a rapid pace.

If there is indeed degradation in math and science literacy in K-12 education, this root cause in the labor supply chain must be addressed. However, as observed in the simulation, even if a greater output of math and science wizards from high-school is created, it will not necessarily solve the problem. In order to create and maintain a healthy domestic STEM economy, something needs to be done to raise and sustain the attractiveness of the STEM field and careers. Otherwise, these high-school graduates will pursue other more attractive careers.
This analysis indicates that boosting STEM literacy in K through 12 education, coupled with systematically retraining the labor force, creates a healthy, sustainable domestic STEM economy. It avoids the need for “hasty” importation of foreign labor and reduces the pressure to off shore jobs due to inflation in wages. Some off shoring of jobs will still occur, to the extent that there are lower wages abroad and current technology allows for remote production. If the root causes of the STEM drainage problem are not addressed, off shoring of jobs, and the importation of skilled labor will continue to escalate.
5. CONCLUSIONS

Sandia National Laboratories in conjunction with The Boeing Corporation have made significant inroads into the understanding of how science and engineering candidates enter into and remain in the workforce. This has shed new light on the potential causes of the decline in qualified US science and engineering candidates. There are still large areas that have not been explored that would provide an even better understanding of the system and help focus the search for potential solutions.

The system is complex with long time delays, and no policy that effects a single variable or a single portion of the system is likely to be successful. Even if the decline in STEM literacy is reversed today, the system will take many years to level off and will not recover to pre-decline levels. It is quite likely that a combination of policies would be more effective.

The work described here has studied employers, the workforce, and visa policies with some exploration of the higher education system. Future work for this project should include additional federal policies such as federal funding for basic research in conjunction with including doctoral candidates in the higher education system and an exploration of public perception and its effects on people entering science and engineering fields.
6. REFERENCES

APPENDIX A: MODEL VIEWS AND EQUATIONS

This appendix contains pictures of the various model views and equations from the Vensim “document” function which will allow for replication of the model in other software programs or programming languages.

The majority of the variables were based on anecdotal evidence or trends, however, those listed below, along with their detailed comments, came from data sources.

“HiE: People with STEM education“

There are about 15M people with STEM educations but only 5M working in STEM jobs (National Bureau of Economic Research, The H-1B Program and Labor Certification: Attestation and PERM, January 18, 2008, Executive Summary)

“W: Avg delay in FN recruitment and petitioning”

About 85% of employer requests for immigrant visas are certified by DOL within 90 days (National Bureau of Economic Research, The H1B Program and Labor Certification, Jan 18, 2008, Executive Summary). We assume an equal amount of time for recruitment. Thus, we use a total of 6 months for recruitment and petitioning

“W: H1B visa quota”

The current annual cap on the H-1B category is 65,000. (Not all H-1B non-immigrants are subject to this annual cap.) The H-1B Visa Reform Act of 2004 makes available 20,000 new H-1B visas for foreign workers with a Master's or higher level degree from a U.S. academic institution. For each fiscal year, 20,000 persons who hold such credentials are statutorily exempted from the cap (USCIS). Over half of H-1B jobs are classified by employers as entry level. The prevailing wage is tied to the job, not to the worker who fills it, which means that if the job requires a BA, an H-1B worker with an MS degree who applies to fill it can be paid a BA-level wage (National Bureau of Economic Research, The H1B Program and Labor Certification, Jan 18, 2008, Executive Summary). Thus, we chose the parameter range to be between 65,000 and 85,000 (the former plus 20,000), assuming that, possibly, part or all of the H-1B visas may be used to fill entry-level jobs
Higher-Level Workers and Vacancies

LA: Normal for recent grads with adv degrees interested in STEM work.

W: Fr HL getting STEM jobs

W: HL vacancies creation rate
W: HL desired vacancy cancellation rate
W: HL adj for vacancies
W: HL layoff rate
W: Initial HL hiring rate
W: Months in a year
W: Months in a year
W: Desired HL workers
W: Labor adj time
W: Labor adj time
W: Expected HL replacement rate
W: Vacancy adj time in months
W: Vacancy adj time in months
W: HL desired layoff rate
W: HL max layoff rate
W: EL promoted to HL

<HiE: Earning graduate degrees>

<HiE: Avg time to fill HL vacancies>

Workers (HL)

"LA: Avg time to fill HL vacancies": base
"W: HL vacancies": base
"J: HL domestic": base
"W: HL workers": base

W: HL workers
W: HL hiring rate
W: Expected time to fill HL vacancies

W: HL retirement rate
W: Expected HL replacement rate
W: Willingness to lay off workers

LA: Normal for recent grads with adv degrees interested in STEM work.

W: Fr HL getting STEM jobs

W: HL vacancies creation rate
W: HL desired vacancy cancellation rate
W: HL adj for vacancies
W: HL layoff rate
W: Initial HL hiring rate
W: Months in a year
W: Months in a year
W: Desired HL workers
W: Labor adj time
W: Labor adj time
W: Expected HL replacement rate
W: Vacancy adj time in months
W: Vacancy adj time in months
W: HL desired layoff rate
W: HL max layoff rate
W: EL promoted to HL

<HiE: Earning graduate degrees>

<HiE: Avg time to fill HL vacancies>

Workers (HL)

"LA: Avg time to fill HL vacancies": base
"W: HL vacancies": base
"J: HL domestic": base
"W: HL workers": base

W: HL workers
W: HL hiring rate
W: Expected time to fill HL vacancies

W: HL retirement rate
W: Expected HL replacement rate
W: Willingness to lay off workers
Imported Labor

- W: H1B visa quota
- W: Time to lift visa cap
- W: Temp immigration
- W: FNs with visas expiring
- W: Avg length of H1B visas
- W: FN work visas petitioned by US companies

<Time>

<LA: Desired number of foreign workers with basic skills>

Foreign Workers

- 130,000 person
- 130,000 person/Year
- 65,000 person
- 65,000 person/Year
- 0 person
- 0 person/Year

Time (Year)

"W: Foreign nationals": base
"W: FN work visas petitioned by US companies": base
"W: Temp immigration": base
Entry-Level Labor Adequacy

LA: Normal fr of recent college grads interested in STEM work

<HiE: Graduating from college>

LA: Recent college grads that sought STEM work

<W: EL hiring rate>

LA: Ongoing labor deficit for EL positions

LA: Last 12 months

<HiE: People with basic degrees eligible for EL jobs>

LA: Recent EL hires

LA: Desired number of foreign workers with basic skills

LA: Perception delay

LA: Normal EL labor to jobs ratio

LA: Normal EL labor pool

LA: Normal avg annual EL pay

LA: Upward pressure on EL wages

LA: Actual avg annual EL pay

LA: Sensitivity of wages to labor adequacy

LA: Upward pressure on EL hiring delay

LA: Normal hiring delay

LA: Avg time to fill EL vacancies

Deficit in Ideal Applicants to EL positions


Time (Year)

0 100,000 200,000 300,000 400,000

Deficit in Ideal Applicants to EL positions (person)

75,000 $/person 0.417 Year

62,500 $/person 0.3335 Year

50,000 $/person 0.25 Year

37,500 $/person 0.1665 Year

25,000 $/person 0.083 Year

EL Labor adequacy vs. Wages & Hiring delay

0.50 0.75 1 1.25 1.50

"LA: Actual avg annual EL pay": base

"LA: Avg time to fill EL vacancies": base

$/person Year

"LA: EL labor adequacy" base

"LA: Actual avg annual EL pay" base

"LA: Avg time to fill EL vacancies" base

0.50 0.75 1 1.25 1.50

"LA: EL labor adequacy" base
Higher-Level Labor Adequacy

LA: Normal & recent grads with adv degrees interested in STEM work

LA: Recent grads with adv degrees that sought STEM work

LA: Last 12 months

LA: Recent HL hires

LA: Desired number of foreign workers with adv skills

LA: Ongoing labor deficit for HL positions

LA: Normal HL labor to jobs ratio

LA: Normal avg annual HL pay

LA: Upward pressure on HL wages

LA: Perceived HL labor adequacy

LA: Sensitivity of wages to labor adequacy

LA: Sensitivity of hiring delay to labor adequacy

LA: Normal hiring delay

LA: Avg time to fill HL vacancies

Deficit in Ideal Applicants to HL positions

HL Labor adequacy vs. Wages & Hiring delay
Continuing Education for EL Employees

- Actual avg annual EL pay
- Normal avg annual EL pay
- Smoothing time
- Smoothed net change in EL labor cost
- EL net desired transfer to indirect worker payments
- Actual employer provided $ per EL worker
- Actual fr of time provided to EL workers
- Normal employer provided $ per EL worker
- Actual number of hours provided per EL worker per year
- Max employer provided $ per EL worker
- Cap multiplier
- Normalized level provided to EL workers
- Effect on fr EL promoted
- Effect on EL LOS
- Effect on lifetime of basic skills
- Cost of training multiplier
- Time to cut loop
- Number of total work hours in a year
- Avg number of hours provided per worker per year

Graphs:
- Actual number of hours provided per EL worker per year
- Smoothed net change in EL labor cost
- Effect on fr EL promoted or EL LOS F
- Effect on lifetime of basic skills F

Data:
- Time (Year):
- Number of total hours:
  - 0, 10, 20, 30, 40
- Time:
  - 0, 0.5, 1, 1.5, 2
- Cost:
  - -15000, -7500, 0, 7500, 15000

Legend:
- "CE: Smoothed net change in EL labor cost"
- "CE: Effect on fr EL promoted" - blue
- "CE: Effect on EL LOS" - green
- "CE: Effect on lifetime of basic skills" - red
Attractiveness of STEM careers

Perceived Attractiveness of STEM Careers


Perceived Attractiveness due to wages

Perceived Attractiveness due to likelihood of getting job

Perceived Attractiveness due to offshoring

Perceived Attractiveness of EL jobs other than wages

Effect of offshoring on attractiveness

Effect of EL wages on attractiveness

Effect of HL wages on attractiveness

Weight on wages

Weight on job availability

Weight on other factors

Sensitivity of attractiveness to EL wages

Sensitivity of attractiveness to HL wages

Sensitivity of attractiveness to EL promotion

Sensitivity of attractiveness to EL tenure

Sensitivity of attractiveness to likelihood of getting job

Sensitivity of attractiveness to offshoring

Sensitivity of attractiveness to EL jobs other than wages

Sensitivity of attractiveness to STEM careers

Weight on other factors @ 2033: 0.4

Base: 1
Model Equations

"Att: Effect of EL promotion on attractiveness" = ( "W: Fr EL promoted to HL" / "W: Normal fr EL promoted to HL" ) ^ "Att: Sensitivity of attractiveness to EL promotion"
Units: Dmnl
:GROUP .internal

"Att: Effect of EL tenure on attractiveness" = ( "W: EL LOS" / "W: Normal EL LOS" ) ^ "Att: Sensitivity of attractiveness to EL tenure"
Units: Dmnl
:GROUP .internal

"Att: Effect of EL wages on attractiveness" = ( "LA: Actual avg annual EL pay" / "LA: Normal avg annual EL pay" ) ^ "Att: Sensitivity of attractiveness to EL wages"
Units: Dmnl
:GROUP .internal

"Att: Effect of HL wages on attractiveness" = ( "LA: Actual avg annual HL pay" / "LA: Normal avg annual HL pay" ) ^ "Att: Sensitivity of attractiveness to HL wages"
Units: Dmnl
:GROUP .internal

"Att: Effect of job availability on attractiveness" = "Att: Recent jobs-filled to graduation ratio" ^ "Att: Sensitivity of attractiveness to job availability"
Units: Dmnl
:GROUP .internal

"Att: Effect of offshoring on attractiveness F" ( [(0,0.5)-(80000,1)],(0,1) , (10000,0.99),(20000,0.96),(26667,0.92),(33334,0.85),(40000,0.75) , (46667,0.65),(53334,0.58),(60000,0.54),(70000,0.51),(80000,0.5) )
Units: Dmnl
:GROUP .table-function

"Att: Effect of offshoring on attractiveness" = "Att: Effect of offshoring on attractiveness F" ( "Att: Total net offshoring" )
Units: Dmnl
:GROUP .internal

"Att: Perceived attractiveness due to likelihood of getting job" = SMOOTHI ( "Att: Effect of job availability on attractiveness", "Att: Time to perceive attractiveness", 1)
Units: Dmnl
:GROUP .metric

"Att: Perceived attractiveness due to offshoring" = SMOOTHI ( "Att: Effect of offshoring on attractiveness", "Att: Time to perceive attractiveness", 1)
Units: Dmnl
:GROUP .metric

64
"Att: Perceived attractiveness due to wages" = SMOOTHI ( "Att: Effect of EL wages on attractiveness"
    * "Att: Effect of HL wages on attractiveness", "Att: Time to perceive attractiveness", 1)
    Units: Dmnl
    :GROUP .metric

"Att: Perceived attractiveness of EL jobs other than wages" = SMOOTHI
    ( "Att: Effect of EL promotion on attractiveness" + "Att: Effect of EL tenure on attractiveness" - 1,
    "Att: Time to perceive attractiveness", 1)
    Units: Dmnl
    :GROUP .metric

"Att: Perceived attractiveness of STEM careers" = "Att: Weight on wages" *
    "Att: Perceived attractiveness due to wages" + "Att: Weight on job availability"
    * "Att: Perceived attractiveness due to likelihood of getting job"
    + "Att: Weight on offshoring" * "Att: Perceived attractiveness due to offshoring"
    + "Att: Weight on other factors" * "Att: Perceived attractiveness of EL jobs other than wages"
    Units: Dmnl
    :GROUP .out

"Att: Recent jobs-filled to graduation ratio" = "LA: Recent EL hires" /
    "LA: Recent college grads that sought STEM work"
    Units: Dmnl
    :GROUP .internal

"Att: Sensitivity of attractiveness to EL promotion" = 1
    Units: Dmnl
    :GROUP .data

"Att: Sensitivity of attractiveness to EL tenure" = 1
    Units: Dmnl
    :GROUP .data

"Att: Sensitivity of attractiveness to EL wages" = 1
    Units: Dmnl
    :GROUP .data

"Att: Sensitivity of attractiveness to HL wages" = 1
    Units: Dmnl
    :GROUP .data

"Att: Sensitivity of attractiveness to job availability" = 1
    Units: Dmnl
    :GROUP .data

"Att: This" = 1
    Units: Dmnl
    :GROUP .this
"Att: Time to perceive attractiveness" = 1
  Units: Year
  :GROUP .data

"Att: Total net offshoring" = "J: Net offshoring of EL jobs" + "J: Net offshoring of HL jobs"
  Units: person/Year
  :GROUP .internal

"Att: Weight on job availability" = 0.25
  Units: Dmnl
  :GROUP .data

"Att: Weight on offshoring" = 0.25
  Units: Dmnl
  :GROUP .data

"Att: Weight on other factors" = 1 - "Att: Weight on wages" - "Att: Weight on job availability"
  - "Att: Weight on offshoring"
  Units: Dmnl
  :GROUP .data

"Att: Weight on wages" = 0.25
  Units: Dmnl
  :GROUP .data

"CE: Actual employer provided $$ per EL worker" = MIN ( MAX ( 0,
  "CE: Normal employer provided $$ per EL worker" –
  "CE: EL net desired transfer to indirect worker payments" ) ,
  "CE: Max employer provided $$ per EL worker" )
  Units: $/person
  :GROUP .internal

"CE: Actual employer provided $$ per HL worker" = MIN ( MAX ( 0,
  "CE: Normal employer provided $$ per HL worker" –
  "CE: HL net desired transfer to indirect worker payments" ) ,
  "CE: Max employer provided $$ per HL worker" )
  Units: $/person
  :GROUP .internal

"CE: Actual fr of time provided to EL workers" = "CE: Actual employer provided $$ per EL worker"
  / "CE: Cost of training multiplier" / "LA: Normal avg annual EL pay"
  Units: Dmnl
  :GROUP .internal

"CE: Actual fr of time provided to HL workers" = "CE: Actual employer provided $$ per HL worker"
  / "CE: Cost of training multiplier" / "LA: Normal avg annual HL pay"
  Units: Dmnl
  :GROUP .internal
"CE: Actual number of hours provided per EL worker per year" = IF THEN ELSE (Time >= "CE: Time to cut loop", "CE: Avg number of hours provided per worker per year", "CE: Actual fr of time provided to EL workers" * "CE: Number of total work hours in a year")

Units: hour

"CE: Actual number of hours provided per HL worker per year" = IF THEN ELSE (Time >= "CE: Time to cut loop", "CE: Avg number of hours provided per worker per year", "CE: Actual fr of time provided to HL workers" * "CE: Number of total work hours in a year")

Units: hour

"CE: Avg number of hours provided per worker per year" = 40
Units: hour

"CE: Cap multiplier" = 2
Units: Dmnl

"CE: Cost of training multiplier" = 2
Units: Dmnl

"CE: Effect on EL LOS" = MIN ("CE: Effect on fr EL promoted or EL LOS F", "CE: Normalized level provided to EL workers")
Units: Dmnl

"CE: Effect on fr EL promoted or EL LOS F" ([(0,0)-(2,2)],(0,0.5),(0.2,0.52),(0.4,0.55),(0.6,0.62),(0.8,0.76),(1,1),(1.2,1.34),(1.4,1.68),(1.6,1.88),(1.8,1.97),(2,2))
Units: Dmnl

"CE: Effect on lifetime of adv skills" = "CE: Effect on lifetime of basic skills F" ("CE: Normalized level provided to HL workers") ^ "CE: Sensitivity of HL professional lifetime"
Units: Dmnl
"CE: Effect on lifetime of basic skills F" ( (0,0)-(2,2), (0,0.5), (0.2,0.52), (0.4,0.55), (0.6,0.62), (0.8,0.76), (1,1), (1.2,1.34), (1.4,1.68), (1.6,1.88), (1.8,1.97), (2,2) )
Units: Dmnl
:GROUP .table-function

"CE: Effect on lifetime of basic skills" = "CE: Effect on lifetime of basic skills F"
( "CE: Normalized level provided to EL workers" )
Units: Dmnl
:GROUP .out

"CE: EL net desired transfer to indirect worker payments" = "CE: Smoothed net change in EL labor cost" * ( 1 - "CE: Normal fr of labor cost changes absorbed by employers" )
Units: $/person
:GROUP .internal

"CE: HL net desired transfer to indirect worker payments" = "CE: Smoothed net change in HL labor cost" * ( 1 - "CE: Normal fr of labor cost changes absorbed by employers" )
Units: $/person
:GROUP .internal

"CE: Max employer provided $$ per EL worker" = INITIAL( "CE: Normal employer provided $$ per EL worker" * "CE: Cap multiplier" )
Units: $/person
:GROUP .data

"CE: Max employer provided $$ per HL worker" = INITIAL( "CE: Normal employer provided $$ per HL worker" * "CE: Cap multiplier" )
Units: $/person
:GROUP .data

"CE: Normal employer provided $$ per EL worker" = INITIAL( "LA: Normal avg annual EL pay" * "CE: Standard fr of work time" * "CE: Cost of training multiplier" )
Units: $/person
:GROUP .data

"CE: Normal employer provided $$ per HL worker" = INITIAL( "LA: Normal avg annual HL pay" * "CE: Standard fr of work time" * "CE: Cost of training multiplier" )
Units: $/person
:GROUP .data

"CE: Normal fr of labor cost changes absorbed by employers" = 0.75
Units: Dmnl
:GROUP .data
"CE: Normalized level provided to EL workers" =
"CE: Actual number of hours provided per EL worker per year"
/ "CE: Avg number of hours provided per worker per year"
Units: Dmnl
:GROUP .internal

"CE: Normalized level provided to HL workers" =
"CE: Actual number of hours provided per HL worker per year"
/ "CE: Avg number of hours provided per worker per year"
Units: Dmnl
:GROUP .internal

"CE: Number of total work hours in a year" = 365 / 7 * 40
Units: hour
:GROUP .constant

"CE: Sensitivity of HL professional lifetime" = 0.5
Units: Dmnl
:GROUP .data

"CE: Smoothed net change in EL labor cost" = SMOOTHI ( "LA: Actual avg annual EL pay"
- "LA: Normal avg annual EL pay" , "CE: Smoothing time" , 0)
Units: $/person
:GROUP .internal

"CE: Smoothed net change in HL labor cost" = SMOOTHI ( "LA: Actual avg annual HL pay"
- "LA: Normal avg annual HL pay" , "CE: Smoothing time" , 0)
Units: $/person
:GROUP .internal

"CE: Smoothing time" = 2
Units: Year
:GROUP .data

"CE: Standard fr of work time" = INITIAL( "CE: Avg number of hours provided per worker per year"
/ "CE: Number of total work hours in a year" )
Units: Dmnl
:GROUP .data

"CE: This" = 1
Units: Dmnl
:GROUP .this

"CE: Time to cut loop" = 1e+009
Units: Year
:GROUP .policy

FINAL TIME = 2058
Units: Year
:GROUP .Control
"HiE: Avg length of college programs" = 4
Units: Year
:GROUP .data

"HiE: Avg length of graduate programs" = 2
Units: Year
:GROUP .data

"HiE: Avg professional lifetime" = "HiE: Normal avg professional lifetime"
* "CE: Effect on lifetime of adv skills"
Units: Year
:GROUP .out

"HiE: Avg skill lifetime for PBDs" = "HiE: Normal avg skill lifetime for PBDs"
* "CE: Effect on lifetime of basic skills"
Units: Year
:GROUP .internal

"HiE: Earning graduate degrees" = "HiE: Students in graduate school" /
"HiE: Avg length of graduate programs"
Units: person/Year
:GROUP .out

"HiE: Entering college" = "HiE: Number of people accepted into STEM programs"
* "HiE: Fr enrolling"
Units: person/Year
:GROUP .metric

"HiE: Entering graduate school" = "HiE: Going directly to graduate school"
+ "HiE: STEM professionals going to graduate school" + "HiE: Others going to graduate school"
Units: person/Year
:GROUP .metric

"HiE: Fr enrolling" = "HiE: Normal fr enrolling after acceptance" *
"Att: Perceived attractiveness of STEM careers"
Units: Dmnl
:GROUP .internal

"HiE: Fr of undergraduate applications rejected" = 0.3
Units: Dmnl
:GROUP .data

"HiE: Fr professionals who pursue graduate ed" = 0.2
Units: Dmnl
:GROUP .data

"HiE: Fr that go directly to graduate school" = 0.2
Units: Dmnl
:GROUP .data
"HiE: Going directly to graduate school" = "HiE: Students in college programs"
/ "HiE: Avg length of college programs" * "HiE: Fr that go directly to graduate school"
   Units: person/Year
:GROUP .internal

"HiE: Graduating from college" = "HiE: Students in college programs" / "HiE: Avg length of college programs"
   - "HiE: Going directly to graduate school"
   Units: person/Year
:GROUP .out

"HiE: Normal avg professional lifetime" = 30
   Units: Year
:GROUP .out

"HiE: Normal avg skill lifetime for PBDs" = 10
   Units: Year
:GROUP .data

"HiE: Normal fr enrolling after acceptance" = 0.75
   Units: Dmnl
:GROUP .data

"HiE: Number of people accepted into STEM programs" = "HiE: Number of people applying for STEM degrees per year"
   * ( 1 - "HiE: Fr of undergraduate applications rejected" )
   Units: person/Year
:GROUP .internal

"HiE: Number of people applying for STEM degrees per year" = "K12: Number of graduates considering STEM degrees"
   * "Att: Perceived attractiveness of STEM careers"
   Units: person/Year
:GROUP .internal

"HiE: Others going to graduate school per year" = 1000
   Units: person/Year
:GROUP .data

"HiE: Others going to graduate school" = "HiE: Others going to graduate school per year"
   * "Att: Perceived attractiveness of STEM careers"
   Units: person/Year
:GROUP .internal

"HiE: PADs becoming obsolete or retiring" = "HiE: People with adv degrees eligible for HL jobs"
   / "HiE: Avg professional lifetime"
   Units: person/Year
:GROUP .internal
"HiE: PBDs becoming obsolete" = "HiE: People with basic degrees eligible for EL jobs"
    / "HiE: Avg skill lifetime for PBDs" - "HiE: STEM professionals going to graduate school"
    Units: person/Year
    :GROUP .internal

"HiE: PBDs retiring" = "HiE: People with obsolete basic degrees" /
( "HiE: Normal avg professional lifetime" - "HiE: Avg skill lifetime for PBDs" )
    Units: person/Year
    :GROUP .internal

"HiE: People with adv degrees eligible for HL jobs" = INTEG( "HiE: Earning graduate degrees"
    - "HiE: PADs becoming obsolete or retiring" , "HiE: Earning graduate degrees"
    * "HiE: Normal avg professional lifetime" )
    Units: person
    :GROUP .out

"HiE: People with basic degrees eligible for EL jobs" = INTEG( "HiE: Graduating from college"
    - "HiE: STEM professionals going to graduate school" - "HiE: PBDs becoming obsolete"
    , "HiE: Graduating from college" * "HiE: Normal avg skill lifetime for PBDs" )
    Units: person
    :GROUP .out

"HiE: People with basic degrees" = "HiE: People with basic degrees eligible for EL jobs"
    + "HiE: People with obsolete basic degrees"
    Units: person
    :GROUP .internal

"HiE: People with obsolete basic degrees" = INTEG( "HiE: PBDs becoming obsolete"
    - "HiE: PBDs retiring" , "HiE: PBDs becoming obsolete" *
( "HiE: Normal avg professional lifetime" - "HiE: Normal avg skill lifetime for PBDs" ) )
    Units: person
    :GROUP .internal

"HiE: People with STEM education" = "HiE: People with basic degrees" +
"HiE: People with adv degrees eligible for HL jobs"
    Units: person
    :GROUP .metric

"HiE: STEM professionals going to graduate school" =
"HiE: People with basic degrees eligible for EL jobs"
    * "HiE: Fr professionals who pursue graduate ed" / "HiE: Avg skill lifetime for PBDs"
    Units: person/Year
    :GROUP .internal

"HiE: Students in college programs" = INTEG( "HiE: Entering college" - "HiE: Going directly to graduate school"
    - "HiE: Graduating from college" , "HiE: Entering college"
    * "HiE: Avg length of college programs" )
    Units: person
    :GROUP .metric
"HiE: Students in graduate school" = INTEG( "HiE: Going directly to graduate school" + "HiE: STEM professionals going to graduate school" + "HiE: Others going to graduate school"
- "HiE: Earning graduate degrees" , ( "HiE: Going directly to graduate school" + "HiE: STEM professionals going to graduate school" + "HiE: Others going to graduate school" ) * "HiE: Avg length of graduate programs" )
Units: person
:GROUP .metric

"HiE: This" = 1
Units: Dmnl
:GROUP .this

INITIAL TIME = 1983
Units: Year
:GROUP .Control

"J: Delay in bringing back EL jobs" = 5
Units: Year
:GROUP .data

"J: Delay in offshoring EL jobs" = 5
Units: Year
:GROUP .data

"J: Desired EL jobs to bring back" = MAX
( 0, "J: EL offshored" * - "J: Relative advantage of offshoring EL jobs"
 * "J: Willingness to bring EL jobs back" )
Units: person
:GROUP .internal

"J: Desired EL jobs to offshore" = MAX
( 0, "J: EL domestic" * "J: Relative advantage of offshoring EL jobs"
 * "J: Willingness to offshore EL jobs" )
Units: person
:GROUP .internal

"J: EL cost per worker threshold" = INITIAL( "LA: Normal avg annual EL pay"
 * "J: Fr above normal avg annual pay" )
Units: $/person
:GROUP .data

"J: EL domestic" = INTEG( - "J: Net offshoring of EL jobs" , "W: EL domestic" )
Units: person
:GROUP .out

"J: EL offshored" = INTEG( "J: Net offshoring of EL jobs" , 0)
Units: person
:GROUP .internal
"J: Fr above normal avg annual pay" = 1.1
  Units: Dmnl
  :GROUP .data

"J: Fr of HL to EL jobs lost due to offshoring" = 0.1
  Units: Dmnl
  :GROUP .data

  Units: person
  :GROUP .data

"J: Net offshoring of EL jobs" = "J: Offshoring of EL jobs" - "J: Offshored EL jobs returning"
  Units: person/Year
  :GROUP .out

"J: Net offshoring of HL jobs" = "J: Net offshoring of EL jobs" * "J: Fr of HL to EL jobs lost due to offshoring"
  Units: person/Year
  :GROUP .out

"J: Normal willingness to offshore EL jobs" = 1
  Units: Dmnl
  :GROUP .policy

"J: Offshored EL jobs returning" = "J: Desired EL jobs to bring back" / "J: Delay in bringing back EL jobs"
  Units: person/Year
  :GROUP .internal

"J: Offshoring of EL jobs" = "J: Desired EL jobs to offshore" / "J: Delay in offshoring EL jobs"
  Units: person/Year
  :GROUP .internal

"J: Relative advantage of offshoring EL jobs" = ( "LA: Actual avg annual EL pay" - "J: EL cost per worker threshold" ) / "J: EL cost per worker threshold"
  Units: Dmnl
  :GROUP .internal

"J: This" = 1
  Units: Dmnl
  :GROUP .this

"J: Time to curb offshoring" = 1e+009
  Units: Year
  :GROUP .policy

"J: Willingness to bring EL jobs back" = 1
  Units: Dmnl
  :GROUP .policy
"J: Willingness to offshore EL jobs" = IF THEN ELSE ( Time >= "J: Time to curb offshoring" , 0.1 , "J: Normal willingness to offshore EL jobs" )
Units: Dmnl
:GROUP .policy

Units: literacy
:GROUP .internal

"K12: Avg STEM literacy at entry" = 0.5
Units: literacy/person
:GROUP .data

"K12: Avg STEM literacy at exit" = "K12: Aggregate STEM literacy" / "K12: Students"
Units: literacy/person
:GROUP .metric

"K12: Desired aggregate literacy" = "K12: Students" * "K12: Targeted STEM literacy"
Units: literacy
:GROUP .internal

"K12: Effect of literacy on interest in STEM career F" ( [(0,0)-(1,2)],(0,0),0.125,0.08),(0.25,0.25),(0.375,0.55),(0.5,1),(0.625,1.45),(0.75,1.75),0.875,1.92),(1,2) )
Units: Dmnl
:GROUP .table-function

"K12: Effect of resource adequacy on targeted STEM literacy F" ( [(0,0)-(1,1)],(0,0),(0,1,0.02),(0,2,0.07),(0,3,0.15),(0,4,0.3),(0,5,0.5),(0,6,0.7),0.7,0.85),(0,8,0.93),(0,9,0.98),(1,1) )
Units: literacy/person
:GROUP .table-function

"K12: Entering 1st grade" = 4.5e+006
Units: person/Year
:GROUP .data

"K12: Fraction of graduates interested in STEM degrees" = "K12: Normal fraction of graduates interested in STEM degrees" * "K12: Effect of literacy on interest in STEM career"
Units: Dmnl
:GROUP .metric
"K12: Graduating from HS" = "K12: Students" / "K12: Length of program"
   Units: person/Year
   :GROUP .metric

"K12: Ideal STEM $$ per student per year" = 2000
   Units: $/person
   :GROUP .data

"K12: Initial number of students" = INITIAL("K12: Entering 1st grade" * "K12: Length of program")
   Units: person
   :GROUP .data

"K12: Length of program" = 12
   Units: Year
   :GROUP .constant

"K12: Literacy change due to resource adequacy" = ("K12: Desired aggregate literacy" - "K12: Aggregate STEM literacy") / "K12: Smoothing time"
   Units: literacy/Year
   :GROUP .internal

"K12: Normal fraction of graduates interested in STEM degrees" = 0.2
   Units: Dmnl
   :GROUP .data

"K12: Number of graduates considering STEM degrees" = "K12: Graduating from HS" * "K12: Fraction of graduates interested in STEM degrees"
   Units: person/Year
   :GROUP .out

"K12: Smoothing time" = 6
   Units: Year
   :GROUP .data

"K12: STEM $$ per student per year" = ("LGo: Aggregate STEM annual budget" + "K12: STEM budget scenario") / "K12: Students"
   Units: $/person
   :GROUP .internal

"K12: STEM budget scenario" = 0 - 1 * RAMP (1.6e+008, 1983, 2008) + 0 * STEP (4e+009, 2008)
   Units: $
   :GROUP .scenario

"K12: STEM literacy entering" = "K12: Entering 1st grade" * "K12: Avg STEM literacy at entry"
   Units: literacy/Year
   :GROUP .internal
"K12: STEM literacy exiting" = "K12: Graduating from HS" * "K12: Avg STEM literacy at exit"
   Units: literacy/Year
   :GROUP .internal

"K12: STEM resource adequacy" = "K12: STEM $$ per student per year" / "K12: Ideal STEM $$ per student per year"
   Units: Dmnl
   :GROUP .internal

"K12: Students" = INTEG( "K12: Entering 1st grade" - "K12: Graduating from HS"
   , "K12: Initial number of students" )
   Units: person
   :GROUP .metric

"K12: Targeted STEM literacy" = "K12: Effect of resource adequacy on targeted STEM literacy"
   F( "K12: STEM resource adequacy" )
   Units: literacy/person
   :GROUP .internal

"K12: This" = 1
   Units: Dmnl
   :GROUP .this

"LA: Actual avg annual EL pay" = "LA: Normal avg annual EL pay" *
   "LA: Upward pressure on EL wages"
   Units: $/person
   :GROUP .out

"LA: Actual avg annual HL pay" = "LA: Normal avg annual HL pay" *
   "LA: Upward pressure on HL wages"
   Units: $/person
   :GROUP .out

"LA: Avg time to fill EL vacancies" = "LA: Normal hiring delay" *
   "LA: Upward pressure on EL hiring delay"
   Units: Year
   :GROUP .out

"LA: Avg time to fill HL vacancies" = "LA: Normal hiring delay" *
   "LA: Upward pressure on HL hiring delay"
   Units: Year
   :GROUP .out

"LA: Desired number of foreign workers with adv skills" = SMOOTH
   ( "LA: Ongoing labor deficit for HL positions" , "LA: Perception delay" )
   Units: person
   :GROUP .metric
"LA: Desired number of foreign workers with basic skills" = SMOOTH
   ( "LA: Ongoing labor deficit for EL positions" , "LA: Perception delay" )
   Units: person
   :GROUP .out

"LA: EL job pool" = "J: EL domestic"
   Units: person
   :GROUP .internal

"LA: EL labor adequacy" = ( "LA: EL labor pool" / "LA: EL job pool" ) /
   "LA: Normal EL labor to jobs ratio"
   Units: Dmnl
   :GROUP .internal

"LA: EL labor pool" = "HiE: People with basic degrees eligible for EL jobs"
   Units: person
   :GROUP .internal

"LA: HL job pool" = "J: HL domestic"
   Units: person
   :GROUP .internal

"LA: HL labor adequacy" = ( "LA: HL labor pool" / "LA: HL job pool" ) /
   "LA: Normal HL labor to jobs ratio"
   Units: Dmnl
   :GROUP .internal

"LA: HL labor pool" = "HiE: People with adv degrees eligible for HL jobs"
   Units: person
   :GROUP .internal

"LA: Last 12 months" = 1
   Units: Year
   :GROUP .constant

"LA: Normal avg annual EL pay" = 50000
   Units: $/person
   :GROUP .data

"LA: Normal avg annual HL pay" = 100000
   Units: $/person
   :GROUP .data

"LA: Normal EL labor to jobs ratio" = INITIAL( "LA: EL labor pool" / "LA: EL job pool" )
   Units: Dmnl
   :GROUP .data

"LA: Normal fr of recent college grads interested in STEM work" = 0.5
   Units: Dmnl
   :GROUP .data
"LA: Normal fr recent grads with adv degrees interested in STEM work" = 0.8
  Units: Dmnl
  :GROUP .data

"LA: Normal hiring delay" = 0.25
  Units: Year
  :GROUP .data

"LA: Normal HL labor to jobs ratio" = INITIAL( "LA: HL labor pool" / "LA: HL job pool" )
  Units: Dmnl
  :GROUP .data

"LA: Ongoing labor deficit for EL positions" = "LA: Recent EL hires" –
  "LA: Recent college grads that sought STEM work"
  Units: person
  :GROUP .internal

"LA: Ongoing labor deficit for HL positions" = "LA: Recent HL hires" –
  "LA: Recent grads with adv degrees that sought STEM work"
  Units: person
  :GROUP .internal

"LA: Perceived EL labor adequacy" = SMOOTH ( "LA: EL labor adequacy" , "LA: Perception delay" )
  Units: Dmnl
  :GROUP .metric

"LA: Perceived HL labor adequacy" = SMOOTH ( "LA: HL labor adequacy" , "LA: Perception delay" )
  Units: Dmnl
  :GROUP .metric

"LA: Perception delay" = 1
  Units: Year
  :GROUP .data

"LA: Recent college grads that sought STEM work" = "HiE: Graduating from college"
  * "LA: Last 12 months" * "LA: Normal fr of recent college grads interested in STEM work"
  Units: person
  :GROUP .out

"LA: Recent EL hires" = "W: EL hiring rate" * "LA: Last 12 months"
  Units: person
  :GROUP .out

"LA: Recent grads with adv degrees that sought STEM work" = "HiE: Earning graduate degrees"
  * "LA: Last 12 months" * "LA: Normal fr recent grads with adv degrees interested in STEM work"
  Units: person
  :GROUP .internal
"LA: Recent HL hires" = "W: HL hiring rate" * "LA: Last 12 months"
Units: person
:GROUP .internal

"LA: Sensitivity of hiring delay to labor adequacy" = 1
Units: Dmnl
:GROUP .data

"LA: Sensitivity of wages to labor adequacy" = 1
Units: Dmnl
:GROUP .data

"LA: Surplus of HL labor" = - "LA: Ongoing labor deficit for HL positions"
Units: person
:GROUP .metric

"LA: This" = 1
Units: Dmnl
:GROUP .this

"LA: Upward pressure on EL hiring delay" = ( 1 / "LA: EL labor adequacy" )
^ "LA: Sensitivity of hiring delay to labor adequacy"
Units: Dmnl
:GROUP .internal

"LA: Upward pressure on EL wages" = ( 1 / "LA: Perceived EL labor adequacy" )
^ "LA: Sensitivity of wages to labor adequacy"
Units: Dmnl
:GROUP .internal

"LA: Upward pressure on HL hiring delay" = ( 1 / "LA: HL labor adequacy" )
^ "LA: Sensitivity of hiring delay to labor adequacy"
Units: Dmnl
:GROUP .internal

"LA: Upward pressure on HL wages" = ( 1 / "LA: Perceived HL labor adequacy" )
^ "LA: Sensitivity of wages to labor adequacy"
Units: Dmnl
:GROUP .internal

"LGo: Aggregate STEM annual budget" = INITIAL
( "K12: Students" * 0.5 * "K12: Ideal STEM $$ per student per year" )
Units: $
:GROUP .data

SAVEPER = TIME STEP
Units: Year
:GROUP .Control
TIME STEP = 0.03125
Units: Year
:GROUP .Control

"W: Avg delay in FN recruitment and petitioning" = 0.5
Units: Year
:GROUP .data

"W: Avg layoff time in months" = 1.5
Units: month
:GROUP .data

"W: Avg length of H1B visas" = 2
Units: Year
:GROUP .policy

"W: Delay to adj prom & LOS" = 2
Units: Year
:GROUP .data

"W: Desired EL workers" = "W: EL labor adj needed" + "W: Expected EL replacement rate"
Units: person/Year
:GROUP .metric

"W: Desired HL workers" = "W: HL labor adj needed" + "W: Expected HL replacement rate"
Units: person/Year
:GROUP .metric

"W: EL adj for vacancies" = ( "W: EL desired vacancies" - "W: EL vacancies" ) / 
( "W: Vacancy adj time in months" / "W: Months in a year" )
Units: person/Year
:GROUP .internal

"W: EL attrition rate" = "W: EL domestic" / "W: EL LOS" - "W: EL promoted to HL"
Units: person/Year
:GROUP .internal

"W: EL desired layoff rate" = "W: Willingness to lay off workers" * 
MAX ( 0 , - "W: Desired EL workers" )
Units: person/Year
:GROUP .internal

"W: EL desired vacancies" = MAX ( 0, "W: Desired EL workers" * 
"W: Expected time to fill EL vacancies" )
Units: person
:GROUP .internal

"W: EL desired vacancy cancellation rate" = MAX ( 0, - "W: EL desired vacancy creation rate" )
Units: person/Year
:GROUP .internal
"W: EL desired vacancy creation rate" = "W: Desired EL workers" + "W: EL adj for vacancies"
  Units: person/Year
  :GROUP .internal

"W: EL domestic" = INTEG( "W: EL hiring rate" - "W: EL layoff rate" - "W: EL attrition rate"
  - "W: EL promoted to HL" , "W: Initial EL hiring rate" * "W: EL LOS" )
  Units: person
  :GROUP .internal

"W: EL hiring rate" = "W: EL vacancies" / "LA: Avg time to fill EL vacancies"
  Units: person/Year
  :GROUP .out

"W: EL labor adj needed" = ( "J: EL domestic" - "W: Entry level" ) / "W: Labor adj time"
  Units: person/Year
  :GROUP .internal

"W: EL layoff rate" = MIN ( "W: EL max layoff rate" , "W: EL desired layoff rate" )
  Units: person/Year
  :GROUP .internal

"W: EL LOS" = DELAY3I
  ( "W: Normal EL LOS" * "CE: Effect on EL LOS" , "W: Delay to adj prom & LOS" ,
  "W: Normal EL LOS" )
  Units: Year
  :GROUP .out

"W: EL max layoff rate" = "W: EL domestic" / ( "W: Avg layoff time in months"
  / "W: Months in a year" )
  Units: person/Year
  :GROUP .internal

"W: EL max vacancy cancellation rate" = "W: EL vacancies" / ( "W: Vacancy cancellation time in months" / "W: Months in a year" )
  Units: person/Year
  :GROUP .internal

"W: EL promoted to HL" = "W: EL domestic" * "W: Fr EL promoted to HL" / "W: EL LOS"
  Units: person/Year
  :GROUP .internal

"W: EL vacancies" = INTEG( "W: EL vacancy creation rate" - "W: EL vacancy cancellation rate"
  - "W: EL vacancy closure rate" , "W: Initial EL hiring rate"
  * "LA: Avg time to fill EL vacancies" )
  Units: person
  :GROUP .internal

"W: EL vacancy cancellation rate" = MIN ( "W: EL desired vacancy cancellation rate"
  , "W: EL max vacancy cancellation rate" )
  Units: person/Year
  :GROUP .internal
"W: EL vacancy closure rate" = "W: EL hiring rate"
Units: person/Year
:GROUP .internal

"W: EL vacancy creation rate" = MAX ( 0, "W: EL desired vacancy creation rate" )
Units: person/Year
:GROUP .internal

"W: Entry level" = "W: EL domestic" + "W: Foreign nationals"
Units: person
:GROUP .internal

"W: Expected EL replacement rate" = "W: EL promoted to HL" + "W: EL attrition rate"
Units: person/Year
:GROUP .internal

"W: Expected HL replacement rate" = "W: HL retirement rate" - "W: EL promoted to HL"
Units: person/Year
:GROUP .internal

"W: Expected time to fill EL vacancies" = "LA: Avg time to fill EL vacancies"
Units: Year
:GROUP .metric

"W: Expected time to fill HL vacancies" = "LA: Avg time to fill HL vacancies"
Units: Year
:GROUP .metric

"W: FN work visas petitioned by US companies" = MAX
( 0, "LA: Desired number of foreign workers with basic skills"
/ "W: Avg delay in FN recruitment and petitioning" )
Units: person/Year
:GROUP .internal

"W: FNs with visas expiring" = "W: Foreign nationals" / "W: Avg length of H1B visas"
Units: person/Year
:GROUP .internal

"W: Foreign nationals" = INTEG( "W: Temp immigration" - "W: FNs with visas expiring" , 0)
Units: person
:GROUP .internal

"W: Fr EL getting STEM jobs" = INITIAL
( "LA: Normal fr of recent college grads interested in STEM work" )
Units: Dmnl
:GROUP .data
"W: Fr EL promoted to HL" = DELAY1
   ( "W: Normal fr EL promoted to HL" * "CE: Effect on fr EL promoted" ,
   "W: Delay to adj prom & LOS" )
   Units: Dmnl
   :GROUP .out

"W: Fr HL getting STEM jobs" = INITIAL
   ( "LA: Normal fr recent grads with adv degrees interested in STEM work" )
   Units: Dmnl
   :GROUP .data

"W: H1B visa quota" = 65000
   Units: person/Year
   :GROUP .policy

"W: HL adj for vacancies" = ( "W: HL desired vacancies" - "W: HL vacancies" ) / 
   ( "W: Vacancy adj time in months" / "W: Months in a year" )
   Units: person/Year
   :GROUP .internal

"W: HL desired layoff rate" = "W: Willingness to lay off workers" * 
   MAX ( 0 , - "W: Desired HL workers" )
   Units: person/Year
   :GROUP .internal

"W: HL desired vacancies" = MAX ( 0, "W: Desired HL workers" * 
   "W: Expected time to fill HL vacancies" )
   Units: person
   :GROUP .internal

"W: HL desired vacancy cancellation rate" = MAX ( 0, - "W: HL desired vacancy creation rate" )
   Units: person/Year
   :GROUP .internal

"W: HL desired vacancy creation rate" = "W: Desired HL workers" + "W: HL adj for vacancies"
   Units: person/Year
   :GROUP .internal

"W: HL hiring rate" = "W: HL vacancies" / "LA: Avg time to fill HL vacancies"
   Units: person/Year
   :GROUP .out

"W: HL labor adj needed" = ( "J: HL domestic" - "W: HL workers" ) / "W: Labor adj time"
   Units: person/Year
   :GROUP .internal

"W: HL layoff rate" = MIN ( "W: HL max layoff rate", "W: HL desired layoff rate" )
   Units: person/Year
   :GROUP .internal
"W: HL max layoff rate" = "W: HL workers" / ( "W: Avg layoff time in months" /
"W: Months in a year" )
Units: person/Year
:GROUP .internal

"W: HL max vacancy cancellation rate" = "W: HL vacancies" /
( "W: Vacancy cancellation time in months" / "W: Months in a year" )
Units: person/Year
:GROUP .internal

"W: HL retirement rate" = "W: HL workers" / "HiE: Avg professional lifetime"
Units: person/Year
:GROUP .internal

"W: HL vacancies" = INTEG( "W: HL vacancy creation rate" - "W: HL vacancy cancellation rate"
- "W: HL vacancy closure rate" , "W: Initial HL hiring rate"
* "LA: Avg time to fill HL vacancies" )
Units: person
:GROUP .internal

"W: HL vacancy cancellation rate" = MIN ( "W: HL desired vacancy cancellation rate" ,
"W: HL max vacancy cancellation rate" )
Units: person/Year
:GROUP .internal

"W: HL vacancy closure rate" = "W: HL hiring rate"
Units: person/Year
:GROUP .internal

"W: HL vacancy creation rate" = MAX ( 0, "W: HL desired vacancy creation rate" )
Units: person/Year
:GROUP .internal

"W: HL workers" = INTEG( "W: EL promoted to HL" + "W: HL hiring rate" - "W: HL layoff rate"
- "W: HL retirement rate" , ( "W: EL promoted to HL" + "W: Initial HL hiring rate" ) *
"HiE: Avg professional lifetime" )
Units: person
:GROUP .internal

"W: Initial EL hiring rate" = INITIAL
( "W: Fr EL getting STEM jobs" * "HiE: Graduating from college" )
Units: person/Year
:GROUP .data

"W: Initial HL hiring rate" = INITIAL
( "W: Fr HL getting STEM jobs" * "HiE: Earning graduate degrees" )
Units: person/Year
:GROUP .data

85
"W: Labor adj time" = 0.5  
    Units: Year  
    :GROUP .data

"W: Months in a year" = 12  
    Units: month/Year  
    :GROUP .constant

"W: Normal EL LOS" = 5  
    Units: Year  
    :GROUP .data

"W: Normal fr EL promoted to HL" = 0.2  
    Units: Dmnl  
    :GROUP .data

"W: Temp immigration" = IF THEN ELSE ( Time >= "W: Time to lift visa cap" ,  
    "W: FN work visas petitioned by US companies" ,  
    MIN ( "W: FN work visas petitioned by US companies" , "W: H1B visa quota" ) )  
    Units: person/Year  
    :GROUP .internal

"W: This" = 1  
    Units: Dmnl  
    :GROUP .this

"W: Time to lift visa cap" = 1e+009  
    Units: Year  
    :GROUP .policy

"W: Vacancy adj time in months" = 1  
    Units: month  
    :GROUP .data

"W: Vacancy cancellation time in months" = 0.5  
    Units: month  
    :GROUP .data

"W: Willingness to lay off workers" = 1  
    Units: Dmnl  
    :GROUP .policy
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