**Kindling a STEM Workforce:  The Importance
of Motivation, Evidence, and Prerequisites for Scale-up**

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Thank you very much for the invitation to attend this meeting. The title of my talk today is, "Kindling a STEM Workforce: The Importance of Motivation, Evidence, and Prerequisites for Scale-Up."  My presentation focuses on four major points:
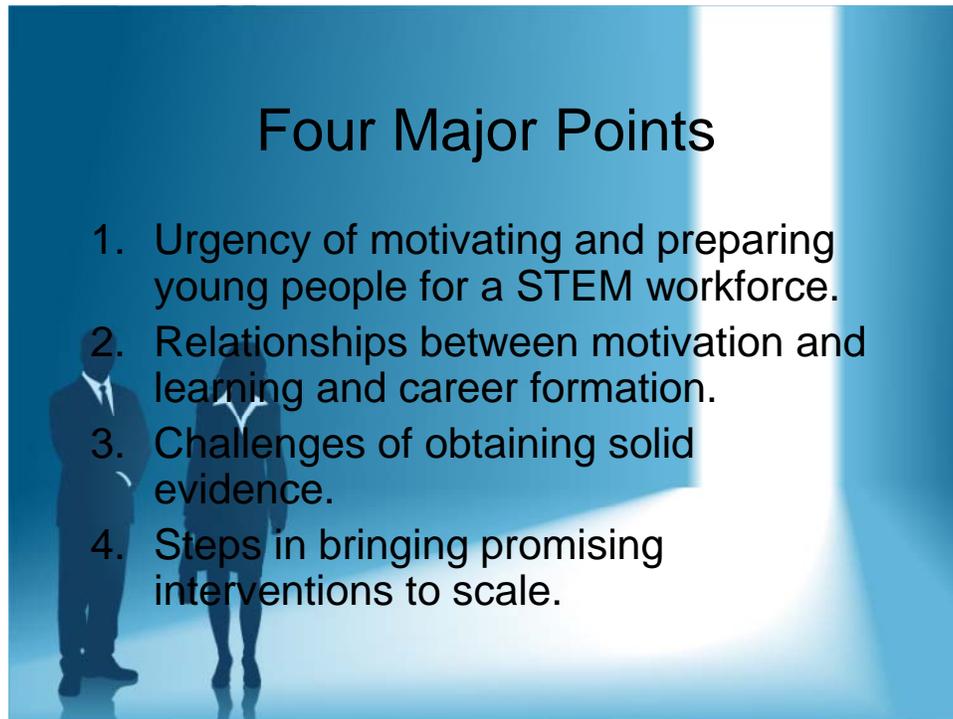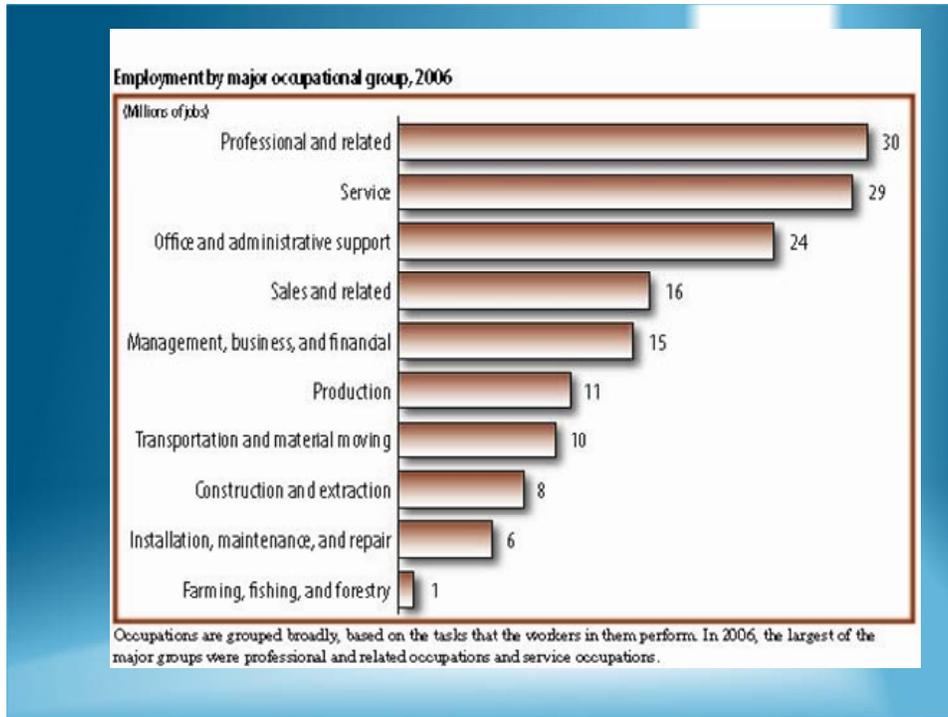


1) the urgency of motivating and preparing young people for a workforce where the fastest growing occupations from 2006 to 2016 are projected to be in STEM-related fields; specifically, network systems, data communications, and analysts (Bureau of Labor Statistics, 2007); 2) the importance of relationships between motivation and learning and career formation, 3) the challenges of obtaining solid evidence about the effects of motivation on academic performance, self esteem, and career formation; and 4) the steps necessary for bringing promising interventions to scale.

**Some Sobering Labor Projections about the World of Information Technology**

Two Sundays ago, I was reading the *New York Times*, and came upon an interesting article by Christopher Caldwell entitled "Old-school Economics," in which he makes a compelling argument that our presidential candidates are focusing too much attention on the plight of factory workers, that make-up only a small proportion of today's labor force, in contrast to other types of occupations also suffering from stagnant wages, non-securable loans, and inadequate health care. Citing data from the Bureau of Labor Statistics, Caldwell points out that in today's economy we have more than 16,000 choreographers compared to less than 2,000 metal-casters, nearly 83,000 people who shuffle and deal cards in casinos compared to about 66,000 who operate lathes, and more than a million security guards compared to about 400,000 machinists in the labor force. Reflecting on these statistics, I thought it would be useful to examine some labor projections for jobs in STEM careers.
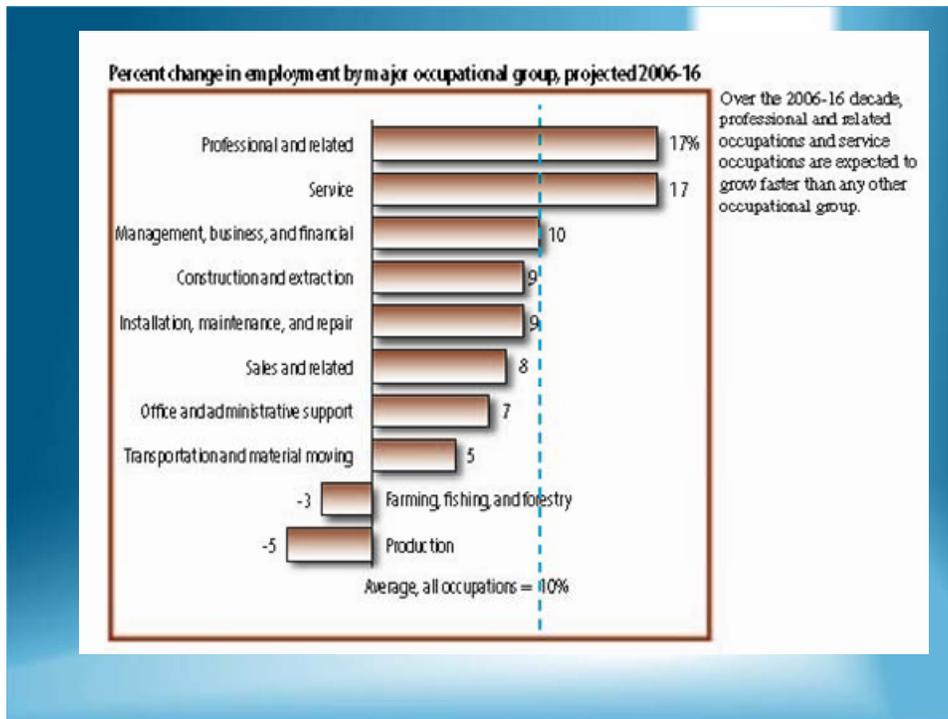
With a click and a tap on the Bureau of Labor Statistics website, and then into the *Occupational Outlook Quarterly Fall 2007,* I began investigating projections for STEM careers. It is useful to underscore that BLS estimates its labor projections not only for occupations expected to have openings from industry job growth but also with respect to replacement; that is, when estimating future jobs they also take into account the number of workers who are likely to leave their present jobs.

What I found, which may be well-known to some of you, was definitely sobering to me.

Employment by major occupational group, 2006
(Millions of jobs)

| Occupational group | Millions of jobs |
|---|---|
| Professional and related | 30 |
| Service | 29 |
| Office and administrative support | 24 |
| Sales and related | 16 |
| Management, business, and financial | 15 |
| Production | 11 |
| Transportation and material moving | 10 |
| Construction and extraction | 8 |
| Installation, maintenance, and repair | 6 |
| Farming, fishing, and forestry | 1 |

Occupations are grouped broadly, based on the tasks that the workers in them perform. In 2006, the largest of the major groups were professional and related occupations and service occupations.
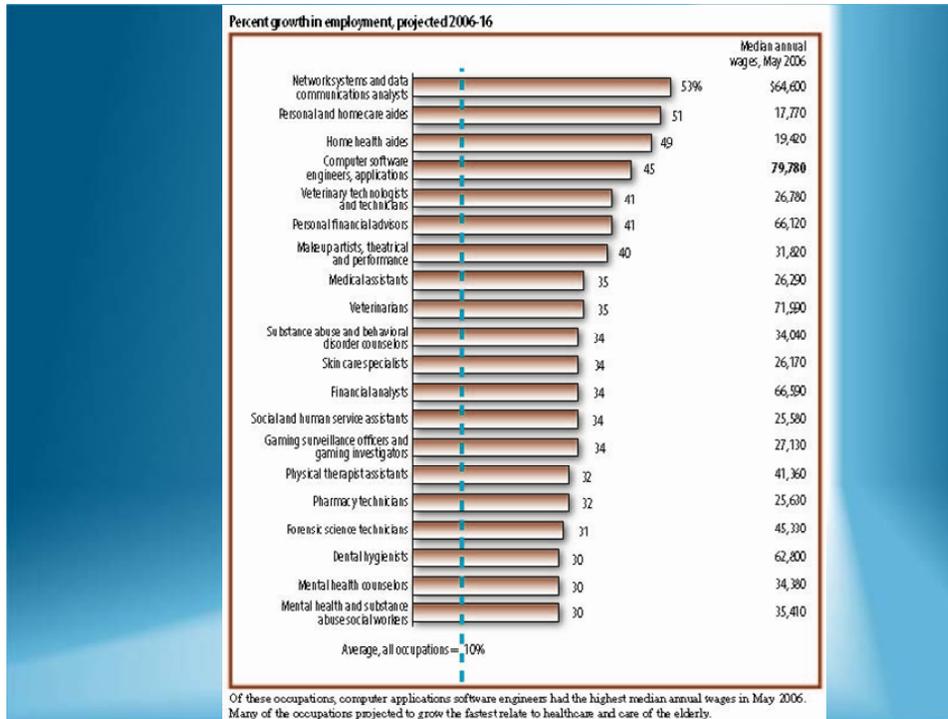
In 2006, the largest fraction of U.S. workers are employed in professional and related occupations, suggesting at least for students aspiring to these occupations, the value and importance of obtaining a postsecondary degree. Professionals account for approximately 30 percent of those in the labor force, nearly twice the number that are in sales, management, and business.

Looking more closely at the professional group, we find that over the next eight years this occupational category, as well as those in the service occupations, is expected to grow faster than any other occupational group.

Percent change in employment by major occupational group, projected 2006-16

Over the 2006-16 decade, professional and related occupations and service occupations are expected to grow faster than any other occupational group.

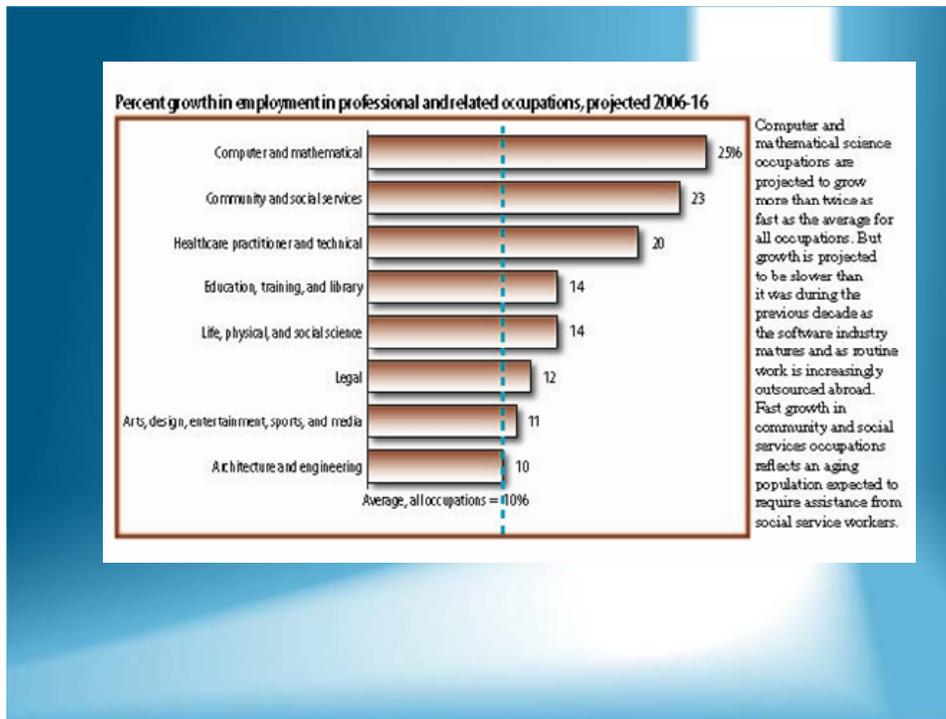| Occupational group | Percent change |
|---|---|
| Professional and related | 17% |
| Service | 17 |
| Management, business, and financial | 10 |
| Construction and extraction | 9 |
| Installation, maintenance, and repair | 9 |
| Sales and related | 8 |
| Office and administrative support | 7 |
| Transportation and material moving | 5 |
| Farming, fishing, and forestry | -3 |
| Production | -5 |

Average, all occupations = 10%

BLS estimates that this group will grow by 17% from 2006 to 2016. As might be expected, the occupational groups losing the most employees are those in production.

Now if you ask the question, what is projected as the fastest growing occupation? For those of us in this room and at NSF, the answer is music to our ears. The fastest growing occupations projected from 2006 to 2016 are in network systems and data communications analysts.

Percent growth in employment, projected 2006-16

| Occupation | Percent growth | Median annual wages, May 2006 |
|---|---|---|
| Network systems and data communications analysts | 53% | $64,600 |
| Personal and home care aides | 51 | 17,770 |
| Home health aides | 49 | 19,420 |
| Computer software engineers, applications | 45 | **79,780** |
| Veterinary technologists and technicians | 41 | 26,780 |
| Personal financial advisors | 41 | 66,120 |
| Makeup artists, theatrical and performance | 40 | 31,820 |
| Medical assistants | 35 | 26,290 |
| Veterinarians | 35 | 71,990 |
| Substance abuse and behavioral disorder counselors | 34 | 34,040 |
| Skin care specialists | 34 | 26,170 |
| Financial analysts | 34 | 66,590 |
| Social and human service assistants | 34 | 25,580 |
| Gaming surveillance officers and gaming investigators | 34 | 27,130 |
| Physical therapist assistants | 32 | 41,360 |
| Pharmacy technicians | 32 | 25,630 |
| Forensic science technicians | 31 | 45,330 |
| Dental hygienists | 30 | 62,800 |
| Mental health counselors | 30 | 34,380 |
| Mental health and substance abuse social workers | 30 | 35,410 |
| Average, all occupations = | 10% | |

Of these occupations, computer applications software engineers had the highest median annual wages in May 2006. Many of the occupations projected to grow the fastest relate to healthcare and care of the elderly.

This group is expected to grow by five times more than the average occupation, which is estimated to increase by only 10 percent.

If you look more specifically at the percentage growth in employment in professional and related occupations category, we find that computer and mathematical science occupations are projected to grow more than twice as fast as the average for all occupations.

Percent growth in employment in professional and related occupations, projected 2006-16

| Occupation | Percent |
|---|---|
| Computer and mathematical | 25% |
| Community and social services | 23 |
| Healthcare practitioner and technical | 20 |
| Education, training, and library | 14 |
| Life, physical, and social science | 14 |
| Legal | 12 |
| Arts, design, entertainment, sports, and media | 11 |
| Architecture and engineering | 10 |

Average, all occupations = 10%

Computer and mathematical science occupations are projected to grow more than twice as fast as the average for all occupations. But growth is projected to be slower than it was during the previous decade as the software industry matures and as routine work is increasingly outsourced abroad. Fast growth in community and social services occupations reflects an aging population expected to require assistance from social service workers.

Percentage growth does not equate to the total number of positions that will be available in a given occupational category. Given the number of projected positions, network systems is third place with slightly less than a million projected positions after health care and education, training, and library, which are expected to grow to slightly more than a million each over the next eight years. Positions in life, physical, and social science fields are also expected to grow but at a lower rate, to nearly a quarter of a million. Even though some have talked about a silver tsunami, because of the graying of the U.S. population, the need for computer and information technology occupations is right up there with health care and care of the elderly.

Traditionally within the social sciences the view of the STEM field is that there is a pipeline problem, that we do not have enough women and minorities to fill positions in engineering, information technology, physics, biology, and other natural sciences. The pipeline problem is not just one of a single tube and getting enough of the right people through it, but

rather we have an emerging acute labor shortage, a labor shortage that extends beyond gender and racial lines, although these imbalances in the STEM population remain a serious problem.

This labor shortage is one that threatens the very competitiveness of the American economy. As many of you are keenly aware, this is a problem that starts early in the education process. If we want to change the number, gender, and racial and ethnic mix of young people entering these fields, we need to begin in the early grades and strengthen that orientation throughout elementary and secondary school and nurture it both in- and out-of-school.

If this is the situation, the critical question becomes:

**How Do We Motivate Young People into STEM Careers?**



Now more than ever young people must learn the skills and values necessary to build successful careers. The close intergenerational tie of taking the job or career of one's parents has been significantly weakened, and young people view their occupational choices as limitless options,

often unrealistic ones. We have relegated to our schools the responsibility for preparing youth for the future, yet few would claim that schools are equipped to prepare youth for the realistic careers that are projected for the decades ahead. We must find better ways to inform youth about the kinds of job and career opportunities, especially those in STEM. Many of these jobs have yet to be conceived of and those recently constructed sometimes become obsolete within a few years. Even more problematic is that few teachers or counselors are familiar with what these new jobs are or the educational and skill requirements they entail.

Our research detailed in the *Ambitious Generation: America's Teenagers Motivated but Directionless* (Schneider, B. and Stevenson, D., 1999) and *Becoming Adult: How Teenagers Prepare for the World of Work* (Csikszentmihalyi, M. and Schneider, B., 2000) found that the most effective way to prepare young people for the labor force is to provide them with two essential learning strategies. The first is to learn the fundamental principles on which a scientifically based society rests. By scientific we do not mean simply the application of the existing hard sciences but rather the generation of a new perspective that integrates the knowledge accumulated in the biological, natural, and social sciences with the wisdom of the humanities from a global perspective. The second is that young people need to develop an equally important set of values and attitudes that are essential for meeting the challenges of the future, no matter what they turn out to be. These values and attitudes are what we consider to be the fabric of motivation, an internal self discipline and skillful use of mind, perseverance, and enthusiasm that promotes self satisfaction, esteem, and desire for future challenges.

Among social scientists there is considerable controversy over what motivation is, why it is important, and how it relates to achievement and career formation.

**What is Motivation?**
**Some Disciplinary Perspectives**

- A psychological approach—person centered
- A sociological approach –contextually centered
- Combined approach—personal attitudes, habits, and motivations interact with social conditions in a reciprocal process of career formation.

If one took a psychological, person-centered approach to explaining why some adolescents go on to have satisfying and productive adult jobs while others do not, one might say what counts is how motivated the teenager is. A good attitude can overcome any obstacle.

A more sociological approach might suggest that many of the attitudes and motivations that help children overcome obstacles or hinder their pursuit of goals are themselves the product of social contexts. One acquires these orientations by interacting with parents, family, friends, teachers, and neighbors. It is easier to be optimistic and highly motivated if the people one knows are successful and secure. Of course there are exceptions, but one can usually find a positive social influence in the life histories of even the most impoverished overachievers.

A combination of the two approaches would suggest that personal attitudes, habits, and motivations interact with social conditions in a reciprocal process of career formation. In studying motivation, we asked students what kind of rewards they seek when they are involved in a difficult task and what they feel about the future. Three rewards emerged:  intrinsic rewards,

those that are inherent to the activity itself; extrinsic rewards, those one receives for doing something whether one enjoys doing it or not; and social rewards, those we obtain from achieving the respect and approval of others.

One could place these findings rather crudely in line with Maslow's contention of a hierarchy of needs. Extrinsic rewards satisfy basic needs, social rewards are the intermediate ones, and the high order intrinsic rewards begin to motivate a person when more immediate necessities are satisfied. Our work on over 7,000 adolescents, 1,221 of whom we followed longitudinally for over ten years, helped us to develop this model of the relationship between motivation and career realism, expectation, and choice.

What we found with respect to motivation reflects on similar models developed by John Carroll, Robert Slavin, and others that highlight the importance of effort, perseverance, and time allocation. This is hardly a new concept; centuries ago Socrates described the key ingredients to learning as being steadfast and not growing weary. These ideas of learning need to be considered in understanding and modeling the process by which young people acquire realistic information about themselves, formulate career options, and develop abilities to formulate a strategy to achieve their goals.

My more favored approach to understanding the acquisition of knowledge and how it crystallizes one's assessment of personal challenges and skills, is the concept of flow, developed my colleague Mihaly Csikszentmihalyi (1990).

**Optimizing the Learning Experience**

- Importance of motivation in learning

- Concept of flow-high challenge/high skill when engaged in an activity perceived as enjoyable

- Relationship of flow to plans for the future especially in fields such as science and mathematics.

Flow is that state when an individual is engaged in an activity that is balanced between being highly challenging and requiring high skill and feeling effortless and all sense of time disappears. Among athletes it is sometimes referred to as being in the zone. This flow state of spontaneity and seemingly effortless work is termed an optimal experience. We have found that young people who spend high proportions of time in flow tend to be more strategic in their plans for the future and are more oriented toward fields such as science and mathematics than students who spend less time in this state.

One of the explanations for this focus on science and mathematics careers, we believe, can be traced and linked to feeling challenged and motivated at school. Students who report high challenge and motivation in their classrooms are more willing to invest in their future schooling. In contrast, students who on a daily basis feel bored, disinterested, and unable to make connections between what they are doing and their futures are less likely to feel committed to school (Schneider, et. al 1995).

Our work on career formation is longitudinal, in that it has followed the same students over time, in this instance ten years, and the data have been analyzed using a variety of statistical models that address issues of sample selection, student prior ability, missing data, and other factors that could undermine our findings. Even though we have considered all of these issues and used sophisticated techniques to ferret out a series of relationships, our results suggest that there is a variety of factors that appear to be associated with career formation, motivation being one of them. These results do not conclusively prove that increasing motivation, even if we could measure it correctly, will **cause** a student to pursue a career in STEM. If one wanted to study the effects of motivation on career formation, where would we start?

**Challenges of Modeling Motivation**

Our research on the relationship between motivation and career formation underscores the importance of beginning a research study with a theoretical model.



Challenges in Modeling Motivation
- Importance of a theoretical model
- Choosing constructs
- Developing links among constructs and outcomes of interest
- Selecting a method or approach
- Assessing the limits of one's evidence

By a theoretical model, I am suggesting that an idea no matter how creative it may be is not sufficient. As the Committee on Scientific Principles for Education Research (Shavelson and Towne, 2002) pointed out, it is imperative to pose a significant question that can be investigated empirically. Moving from a hunch to conceptualizing and specifying a worthwhile question is essential to scientific research. The question and the designs developed to address them must reflect a solid understanding of the relevant theoretical, methodological, and empirical work that has come before. Every scientific inquiry is linked, either implicitly or explicitly, to some overarching theory or conceptual framework that guides the entire investigation. Science generates cumulative knowledge by building on, refining, and sometimes replacing theoretical understandings.

This focus on the theoretical model is central to all research. At the initial stages of our research on career formation, we had several assumptions about how young people form ideas about careers and published a series of pieces on the theoretical models that would guide our work (Schneider, 1994).

The development of one's model should include some assumptions or hypotheses about links among constructs and the unit of investigation. Defining the constructs is part of one's model formulation. One could find multiple definitions of motivation, and this presents a real challenge to the researcher who has to choose a definition that is theoretically justifiable, can be identified through a set of constructs, and expresses a relationship to the outcome of interest. In our study we defined motivation as a composite variable, calculated as the mean of a number of variables consisting of what one wishes to be doing, enjoys what one is doing, and finds the activity interesting.

The next consideration in the process is selecting the method or approach by which that question will be investigated. Methods can only be judged in terms of their appropriateness and effectiveness when addressing the research question under consideration. Particular research designs and methods are suited for specific kinds of investigations and questions. One method or statistical procedure can rarely illuminate all lines of inquiry. Scientific claims are strengthened when they are subject to testing by multiple methods.

For example, in addition to the longitudinal data we obtained from our adolescents, we also conducted intensive face-to-face interviews, observed the students' schools and neighborhoods, and sometimes made visits to their homes. One key source of data we obtained was through the Experience Sampling Method, a form of time diary that measures how an individual feels at various times during different activities each day over the course of a week. These data were combined and analyzed with survey and intensive interview data to answer a series of questions about career formation.

In the early stages of our work, we found that motivation is positively associated with self-esteem and future goals. We suspected that enjoyment of a school activity is linked with the importance and relevance the activity has to the individual. However, in subsequent analyses we found a strong negative relationship between being in an academic class and feeling motivated. We suspected that this finding is the consequence of most academic classroom activities being inherently less enjoyable and uninteresting than non-academic activities. However, academic classrooms were perceived as more challenging, skill-related, and anxiety producing than classrooms in other subjects.

Testing one's theoretical model is an iterative process. We begin with a set of ideas, test them and then test them again and again changing measures, rebuilding constructs, and seeking

new relationships. What has not been established is whether high motivation, or an unusual effort or desire to succeed, affects actions or attitudes related to career formation. The search for cause is not the same as finding an association between constructs. More problematically, there are only a few models that allow us to estimate effects. Only by using certain types of designs can one find effects that can be brought to scale.

**Bringing Interventions to Scale**

In the recent ITEST program solicitation there is a section on Scale-Up Projects. What is a scale-up project? These are ideas we have been wrestling with for the last six years and, with NSF support, have produced a series of articles and more recently a two volume work on *Scale-Up in Education: Ideas in Principle* (Schneider, B. and McDonald, S-K., 2007) and *Scale-Up in Education: Issues in Practice* (Schneider, B. and McDonald, S-K., 2007).



Bringing Interventions to Scale

- Scale-up is the enactment of interventions whose efficacy has been established in specific contexts, with the goal of producing similarly positive effects with larger populations in diverse settings.

Scale-up is the enactment of interventions whose efficacy has already been established in specific contexts, with the goal of producing similarly positive effects with larger populations in diverse settings.

Let's start with an example and assume we have a motivation program that when implemented will increase interest is STEM careers. In this case the effect is an increased interest in STEM careers. An effect is that which had its beginning from some other thing. A cause is that which makes another thing. We rarely know all the causes of observed effects or how they relate to one another. So instead we seek to create designs that allow us to have confidence in the probability that an effect will occur.

The gold standard for estimating the effect of a program is achieved by a randomized control trial (RCT).



## Randomized Control Trials

- In an RCT two groups of students are selected for an experiment, one group receives the program the other does not.
- The power of random assignment is that on average, the two groups that are selected are initially the same, differing only in terms of the intervention.

As described in *Advancing Scientific Research in Education* (Towne et al., 2004), randomized control trials in education, when they are feasible and ethical, are highly effective methods for gauging the effects of interventions on educational outcomes. In an RCT two groups of students are randomly selected for an experiment, and one group receives the program while the other does not. The power of random assignment is that, on average, the two groups that are selected are initially the same, differing only in terms of the intervention. This allows researchers to be more confident about attributing observed differences between the two groups to the intervention, rather than to known and unknown factors that influence human behavior and performance.

As in any comparative study, researchers must be careful to observe and account for any confounding variables that could differentially affect the groups after randomization has taken place. That is, even though randomization creates statistically equivalent groups at the onset, once the intervention is under way, other events or programs can take place in one group and not the other, undermining any attempt to isolate the effect of the intervention.

Individual studies indicate only that the intervention works in a particular setting. To determine whether an intervention is scalable, it is necessary to conduct multiple studies in various settings and with different populations of students. The goals in conducting multiple studies are to generate a body of evidence that demonstrates that the intervention can produce similar positive results across settings and populations.

Scale-up is a developmental process that begins with what is commonly called proof of concept and then is tested usually in two additional phases.

To establish proof of concept we begin by testing an intervention with a small population, and then in the next stage we increase both the number of subjects--students and the schools that they are in. These efficacy trials determine whether an intervention produces the expected result under ideal conditions. Accumulating results from multiple trials of an intervention is a second and essential stage of scale-up research. Where contexts are fixed, scaling can be achieved through replication. However, significant modifications may be required to produce identical results when contexts differ.

   We are now in the middle of an efficacy trial. Based on the findings from our career formation studies, with support from the National Institute of Health we developed a small random clinical trial to determine if we could change the career paths of students in high school. Based on this initial small study, we have now moved to a larger school-based intervention that is designed to promote a college-going culture in high school and increase the number of low-

income students, who might not ordinarily attend college, to enroll and persist in postsecondary institutions.

The third stage in scale-up research involves the ongoing evaluation of implementations to enrich understanding of the factors influencing efficacy and sustainability. Here is where the researcher substantially increases the size of the population under study and increases the variation in the classroom, school, district, or other context in which the intervention occurs. It is the variability introduced by these contextual differences that creates uncertainty regarding the potential of an intervention being brought to scale. It is at this stage that questions about the depth of the results of the intervention are raised. We refer to these as effectiveness trials as they measure the variability of effects under real world conditions.

Educational scale-up research is methodologically sophisticated and analytically complex. Researchers moving into this area should do so with considerable expertise and consultation with others who have had experience not only in designing such studies but conducting and analyzing the results as well.

For example, there are a number of conditions that researchers face in scale-up

**Challenges in Scale-Up Research**
- Internal and External Validity
- Statistical Power and Sample Size
- Producing Robust Generalizable Findings

work, including internal and external validity; statistical power and sample size; and methodological tools that researchers can use to produce robust, generalizable findings. The major concern of the researcher is ruling out factors other than the intervention that could plausibly account for variation in the outcome variable.

Some of the threats to internal validity refer to whether the outcomes of interest are attributable to differences in subjects rather than the treatment condition. For example, some students may drop out of the program, some students may do well regardless of the program, and some students may never participate—we call these non-compliers. Some students may feel so demoralized that they do poorly because they are not in the program, or alternatively they may work harder to show that they can do just as well. Another problem is whether the program is executed with fidelity, meaning the program is fully implemented according to the scripted protocol that describes all of the conditions and procedures that need to be executed.

If evidence of scalability is to be provided, researchers have to determine to what extent conditions in classrooms under study are representative of those in other schools and show that similar statistical power can be achieved when additional classrooms or schools are added to the study. Professor Larry Hedges has developed a program to address this need, and is currently engaged in work to compute the sample size needed to detect a treatment effect in a given population before conducting an experiment with schools of differing characteristics, such as the proportion of students in the school receiving free lunch.

My colleague Sarah-Kay McDonald and I wrote an article in the *Educational Researcher* (McDonald, S.K. et al, 2006) where we argue about the importance of taking a rigorous approach to scale-up research. In this article we stress not only the design and statistical considerations in bringing an intervention to scale but also the importance of undertaking close collaborations with practitioners so that the interventions can be tested in settings where possible threats to internal and external validity can be controlled and monitored. We also underscore the value of using other methodological approaches in conjunction with RCTs. Additional methods such as observational studies can richly describe the implementation of the intervention and sharpen the ability to understand and isolate the influence it has on outcomes.

Scale-up research is not meant to prescribe a course of action for all schools. Scale-up is not a euphemism for the uncritical diffusion of interventions shown to have a positive impact on student learning in one setting to different teacher and student populations in diverse and dynamic circumstances. On the contrary, scale-up research has to be thoughtfully and carefully designed so that such studies can provide persuasive evidence of an intervention's effectiveness in different contexts. Hopefully, I have not posed too many challenges and that many of you will

be motivated to take the plunge into scale-up research –helping us to learn what successful

practices will in fact motivate young people to seek careers in STEM fields.

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