INTRODUCING THE TRILOGY OF SUCCESS: EXAMINING THE ROLE OF ENGAGEMENT, CAPACITY AND CONTINUITY IN WOMEN'S STEM CHOICES

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Abstract *—For many years, there have been efforts to increase women's preparation for and participation in STEM (Science, Technology, Engineering and Mathematics). While sex differences in pre-college math/science course-taking and achievement have declined dramatically and the math course-taking gap has almost closed, men, however, remain four times as likely to choose an engineering major. It is clear that women's STEM under-representation is more complex than earlier imagined and that a focus on any one factor, no matter how necessary, will not lead to success. Successful continuation appears to be related not to one, but to three interrelated factors:*

> *Engagement: Having an approach to STEM that includes such qualities as awareness, interest and motivation.*
> *Capacity: Possessing the knowledge and skills required to advance to increasingly rigorous SMET content.*
> *Continuity: Having institutional and programmatic opportunities that support advancement to increasingly rigorous SMET content.*

Index Terms— capacity, continuity, engagement, retention, theory.

INTRODUCTION

For many years, there have been efforts to increase women's preparation for and participation in STEM (Science, Technology, Engineering and Mathematics). Early efforts were based on an assumption that once given opportunities to do math and science, women would continue on in STEM majors and careers. There is a basis to this: for women to go on in STEM it is necessary for courses and other STEM experiences to be available to them.

Access was opened to middle class, predominately white girls, and sex differences in pre-college math/science course-taking and achievement declined dramatically. The course-taking gap has almost closed. For example, in 2003 women were 51% of the SAT I students taking Calculus in high school, and 50% of those who expect advanced standing in Math in college courses. Both young women and men took on average 3.8 years of math in high school and had the same math grades (3.1 on a four point scale) (College Board, 2004). With the exception of the SAT: Math where young men continue to outscore young women by a third of a standard deviation (34 points on a 200-800 scale, a difference that has remained consistent for years), there are only small differences in standardized test scores. In 2001 the National Center for Education Statistics reported that, "The gap between the average scale scores of males and females is quite small at all three grades [in which the NAEP is conducted] and has fluctuated only slightly over the past 10 years" (NCES, 2001, p. 10).

Women have the background, the achievement and the courses necessary to major in STEM at the same rate as men. Yet men remain four times as likely to choose an engineering major (College Board, 2004; National Science Foundation, 2004; Clewell & Campbell, 2002). The assumption that women have all they need to continue on in STEM is only partially correct. While background and knowledge are necessary for women's entry into engineering, the data indicate they are not sufficient.

A second assumption was based upon the belief that if girls and women knew more about STEM careers and had more positive attitudes about STEM, then they would continue on in STEM majors and careers. This assumption was based on research showing that males consistently reported more positive attitudes towards science than females and that girls are more apt to see math and science as the domain of white males and are less apt to see themselves as successful practitioners of math and science, and that they do not enjoy these subjects (Clewell & Campbell, 2002; Catsambis, 1995; Fennema & Sherman, 1978). Since, it was assumed, those who don't enjoy a field or feel they can't do well in it tend not to continue in it and with better attitudes and more academic self confidence in STEM will come increased participation in STEM majors and careers. Programs based on this assumption may have contributed to girls' and women's confidence and to their entry into higher level courses, however there is not data to indicate that these types

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of programs have increased the number of women going into STEM, including engineering (Clewell & Darke, 2000; Campbell, Jolly, Hoey & Perlman, 2002).

THE TRILOGY

It is clear that women's under-representation in STEM is more complex than earlier imagined and that a focus on any one factor, no matter how necessary, will not lead to success. Successful continuation appears to be related not to one, but to three interrelated factors:

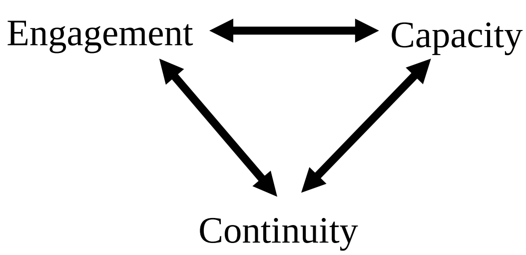

FIGURE. 1
THE TRILOGY

The factors are defined as follows:

> Engagement: Having an approach to STEM that includes such qualities as awareness, interest and motivation.
>
> Capacity: Possessing the knowledge and skills required to advance to increasingly rigorous STEM content.
>
> Continuity: Institutional and programmatic opportunities and material resources that support advancement to increasingly rigorous STEM content. (Jolly and Campbell, 2002)

Individually, each of these features is not sufficient for advancement along the STEM pathway, specifically the engineering pathway. For example, if the educational system is aligned for continued student advancement and the student has high interest in engineering but has failed to achieve the requisite skills to advance to the next level, she simply will not be able to advance. Similarly, if students have succeeded in content mastery and the educational system supports their further advancement but they have no interest, they will also leave the engineering pipeline. And finally, if the student has competency and interest but the system does not offer such opportunities as Calculus, AP courses and information on colleges at the precollege level or access to mentors, financial aid and research and design experiences at the college level, then advancement is at best very difficult.

There are some efforts that address all three areas including the Gateway to Higher Education, a New York City public school based program designed to increase the numbers of minority students in the sciences. Gateway builds student capacity by having an extended school day with double periods of math or science with all science courses having laboratory components, after school tutoring and summer programs. Gateway covers issues of continuity through making AP and other advanced courses available to students, providing students and parents with information about college including college visits, an annual college fair, SAT I and II prep and seminars for parents on college financial aid. To increase student engagement students participate in internships, are exposed to science professionals, participate in field trips to museums and even attend the theater, the opera and the symphony. A controlled study found Gateway working well, with Gateway students being more apt to take advanced math and science courses, do well in them, move on to college in greater numbers and continue on in the sciences (Campbell et al., 1998).

A second example focuses on middle school girls. The "Dr. C.D. Turnage Science, Math and Technology Scholars Program" serves five rural, economically disadvantaged, predominantly African-American school districts in North Carolina. The project builds capacity and engagement by providing hands-on activities, field trips and a STEM oriented summer camp held at a college. To increase continuity, teachers, counselors and school staff are engaged in professional development centered on equitable instructional delivery practices. And to further facilitate engagement, parents are also included in activities and discussions of gender equity issues. Interim evaluations showed quantitative and qualitative gains for participating students in math and science grades and attitudes and interest in STEM. Measurements of teachers' attitudes and practices showed gains in awareness and use of gender equity strategies in the classroom pre- to post-intervention. Surveys of parent participants reveal they feel more confident about their daughters' abilities and more willing to support girls' pursuit of science and math education and careers (Clewell and Darke, 2000).

While the preceding examples address all three areas, this does not have to be the case. Individual educational programming may only be designed to advance one aspect of this trilogy, as long as the experience of every student includes all three areas. There must be coherence[4] between programs and people so that these factors which are each

[4] Coherence: A logical and mutually beneficial consistency among elements to support a shared goal.

necessary for success can be identified collectively for every student and lacks in an individual's experience can be addressed. We must recognize that each of these elements is necessary, but none alone are sufficient to support advancement in engineering. It is not enough that reformers support efforts in engagement, capacity and continuity; we must assure that these efforts are overlapping sets in each student's experience. This consideration can help identify both the elements of reform activities and the evaluation of these activities.

In each area there are a myriad of approaches, including many in informal as well as formal programs, for supporting student development. For example, parents, colleagues, siblings and mentors are often important players in supporting a students' interest, esteem, sense of efficacy and even the joy that is referred to by *Engagement*. Similarly, this same group can serve as important guides for navigating career paths, supporting AP enrollment, accessing college financial aide and providing the many other guideposts that support *Continuity*.

Applying the trilogy has applications for program evaluation as well. In evaluating the impact of intervention strategies on each student it is possible to operationalize the indicators of success. There is evidence of increased engagement when a student expresses an interest in future course sequences, can identify the requisite skills of a STEM profession, understands which courses are necessary for advancement, can clearly envision themselves within a profession and spends their own time on STEM activities. We are increasing capacity when the student masters a discrete knowledge base and demonstrates a skill set that allows further advancement in learning. And we increase continuity when a system has an aligned sequence of classes and courses that are equally available to all students and that each student is able to navigate the system for continuing advancement.

While evaluations can be designed to determine the presence and quality of efforts to increase engagement, capacity and continuity, this is not enough. Key is the degree to which the program efforts match individual student needs. For example, a student with high engagement whose education provides strong continuity may only need to be provided with instruction to improve their capacity. Programs and reform efforts should include all three areas but they also need to assess the degree to which the students they serve have needs in each of these areas. This assessment should be done prior to the design of the program and/or the reform. Once this is done, process evaluation can then focus on the match between student needs and program/reform components along with looking at student longer term participation in engineering.

While the application of the trilogy can have strong implications for assessing student needs, designing and evaluating programs and even determining policy, it must be remembered that it is a theory. While there are strong arguments for this model and its utility as an organizing framework, it is a model that needs to be tested. That is the next step.

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