AN ASSESSMENT MODEL TO DRIVE UNDERGRADUATE EDUCATIONAL REFORM IN THE SMET FIELDS IN A LARGE PUBLIC MULTICAMPUS UNIVERSITY SYSTEM

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Introduction

Educational reform at the undergraduate level requires an institutional cultural transformation. Individual efforts of reform oriented proactive faculty are necessary, but not sufficient. If a true reform is going to take place and is to be sustained, a systemic strategic plan that analyzes the whole system and identifies the strengths and weaknesses of the educational pipeline is needed. The plan also must identify the key pressure points that will catalyze the desired change and mechanisms that will nurture, protect, and incentivize the agents of change and their capacity to influence the rest of the system.

At the University of Puerto Rico (UPR) Multicampus System (with a 68,000 student body, eight 2- and 4-year colleges, and three graduate, Ph.D. offering, campuses), a two prong approach was found to be essential to guide, incentivize, and nurture the reform. A virtual organization, located at the Office of the President of the University System, was established as a Reform Institute parallel to the regular academic management structure and designed to interact closely with top management and cadres of reform oriented faculty.

The two prong approach consisted of two major thrusts. The first was directed to the CEO's of the different campuses of the System with the expressed objective of providing key systemic evaluation indicators that measure the effectiveness and

efficiency of the undergraduate educational enterprise and influencing major policy decisions that would institutionalize and accelerate educational reform. The second was directed to faculty with the objective of nurturing the formation of a coherent cadre of reform oriented professors who would experiment with new teaching/learning approaches, pilot test them, and then spearhead major systemic reform efforts.

The orchestration of this two-prong approach was under the academic management of the Resource Center for Science and Engineering (RCSE). Acting as a virtual organization, the Resource Center obtained external funds, mostly from the NSF, through the AMP project, to energize and catalyze the reform; conducted an extensive evaluation of the effectiveness and efficiency of the teaching/learning environment and activities; identified weaknesses and strengths; and promoted a strategic plan that would exploit key pressure points for initiating the reform. The RCSE then forged strategic alliances of reform oriented faculty and nurtured pilot projects that experimented with new teaching/learning strategies grounded on the latest cognitive science and educational literature and on exemplar national projects. Simultaneously, the Center pioneered the development of metrics and benchmarks to measure the performance of the teaching/learning enterprise of the University System, measured these key systemic variables, and used them to persuade the CEO's of the different campuses of the need for reform.

The result of this five-year initiative that is now in its second five-year phase has been an institutional culture transformation of the educational enterprise in key units of the system. CEO's of the academic units have been persuaded of the importance of Institutional Research to measure progress and locate points of ineffectiveness or

inefficiency, guide strategic planning, and the allocation of resources on the basis of quality and output of department and colleges. In two of the campuses, well conceived Faculty Development programs have been put implemented to improve faculty teaching/learning skills and strategies. Institutional resources have been allocated to scale-up successful pilot projects pioneered by the cadre of reform-minded faculty; and a program is being instituted for the professional development of the middle academic management of the institution so that they will be effective supporters of the reform. The effort is known as the Academy for the Improvement of the Middle Management Support of the Reform (AIMMS).

After five years of the reform effort, the number of Science, Mathematics, Engineering, and Technology (SMET) graduates per year have gone from 1,709 in 1991 to 2,674 in 1996--an increase of 56% in five years; this has been achieved without a significant increase in SMET enrollment. Thus, reflecting an increase in the effectiveness and efficiency of the educational process. These changes have been driven by a systematic measurement of graduation rates (GR) that have increased during the five year period, and by the assessment of the effectiveness and efficiency of the gatekeeper courses in the SMET disciplines measured by an index of course efficiency (ICE) which has driven efforts to revise gatekeeper and bottleneck courses. The quality of graduates from the SMET programs has been measured through a proxy indicator or variable, the number of SMET Bachelor graduates who pursue and complete a Ph.D. in these fields. One of the campuses has achieved what can be considered as an outstanding result, even when benchmarked against National Statistics; ten out of every hundred of its graduates from the B.Sc. programs go on to complete a Ph.D. in SMET at some of the top Ph.D. graduating institutions of the

Nation.

Key Systemic Metrics and Benchmarks as Vehicles to Drive Reform

When the AMP project started six years ago, the Institution had few systemic indicators and these were not used in any systematic fashion by CEO's to guide their decision and policy making processes; thus, decision making was based mostly on intuition, guess work, and realpolitik. The AMP project developed a strategic plan to remedy this deficiency and achieve systemic reform in SMET programs. It started by studying the undergraduate SMET pipeline and finding its major ineffective and inefficient points; a series of courses were identified as the major source of the problem. Two categories of courses were identified: the gatekeeper courses (Pre-calculus and Calculus, Introductory Chemistry and Physics), where the greatest attrition of SMET students took place; and the bottleneck upper division or upper level courses that students had difficulty in approving and prevented SMET majors from graduating.

Multicampus assessment teams were assembled to evaluate the curriculum-content, teaching/learning strategies and methods, and classroom assessment of the gatekeeper courses. The teams then did an extensive evaluation of these courses and drew, by consensus, major recommendations for their improvement. Cadres of reform oriented faculty were identified and pilot projects initiated to improve the teaching/learning process in these courses. Working groups were also formed to introduce cooperative learning methods in both gatekeeper and bottleneck courses and a special program was developed for at-risk students--those students who, by the use of several indicators, had a high probability of dropping out of the SMET pipeline to develop their study/learning skills

within the context of a course (TADDEI, by its Spanish acronym).

Following the pipeline metaphor, a longitudinal cohort study was undertaken to identify the major obstacles to graduation and the nature of these impediments. Student records, not including student names to protect their privacy rights, of a scientifically selected random sample of SMET students from all campuses of the University of Puerto Rico, were studied and analyzed by campus and discipline. From this longitudinal cohort study, the following useful information was obtained: average time to graduate, year to year retention rates, percentage of cohort in good standing as they move through the pipeline, **graduation rate**, percentage of SMET students who transfer to other disciplines, and average number of attempts needed to pass satisfactorily (A, B, or C) gatekeeper and bottleneck courses. The **SMET graduation rate**--which was defined as the percentage of entering SMET students who managed to graduate in a period of seven years since admission (average time to graduate plus two years)--**and the ICE**--which was defined as the number of students in the cohort who took a course (including multiple attempts), divided by the number of students in a cohort who passed satisfactorily a specific course (thus, an ICE index of 1 would mean that every student passed the course on the first attempt, and an index of, say 2, would mean that a student on the average would approve the course, after enrolling in it two times)--were the two most useful indicators for the purpose of persuading the upper academic management, as well as faculty, of the need for reform. The ICE indicator, for example, convinced the Chancellors of two of the UPR campuses to institute Faculty Development programs and to establish special incentives to improve courses with high ICE numbers (high ICE indicates low efficiency).

To measure the quality of graduates, a proxy variable was designed that measured the number of students that completed a Ph.D. in SMET after graduating with a B.Sc. from these disciplines from the university. The data for this study was obtained from the National Academy of Sciences - National Research Council, Ph.D. study. Other indicators of quality were obtained by anecdotal means from interviews of B.Sc. graduates from UPR. A more systematic study of the performance, after graduation, of a random cohort of graduates is needed and will be included as part of the Institutional Research initiative that is being developed. Also included in the metrics was the total number of SMET degrees by campus, discipline, and gender, as required by NSF. These indicators--which had a specific benchmark of 2,600 SMET B.Sc. graduates for the first five years and of 4,000 for the second phase of AMP project--have been powerful tools for approving key policies and driving the reform.

Whenever possible, national benchmarks were identified to serve as indicators of progress in achieving the goals of the reform. For example, the flagship programs of Engineering (Mayagüez Campus) and Natural Sciences (Río Piedras Campus) have been benchmarked against graduation rates of the University of Illinois at the Urban Campus. The Engineering School has already achieved its goal of equaling the graduation rate of 76% of that Institution.

The rigorous assessment of the pilot reform projects has been an essential element to persuade CEO's and faculty to adopt strategies and methods pioneered by the pilot courses and to scale-up these courses to department or collegewide level using institutional resources. Evidence of increased performance of pilot courses--using cooperative learning;

TADDEI program; integration of laboratory and class, with emphasis on the development of concepts in Physics; use of technology and innovative teaching strategies in the Pre-calculus/Calculus sequence; and a conceptually hands-on based course in Chemistry that also revised the class assessment tools to emphasize depth of understanding--are being used to drive the reform and has helped set institutional strategic planning on a rational basis.

Systemic Outcomes and Conclusions

Based on an educational pipeline model, the SMET fields at the University were analyzed and a strategic plan was implemented to increase the effectiveness and efficiency of the educational enterprise and to transform the teaching/learning institutional culture. The reform was driven by a carefully designed assessment

system that concentrated in the development of systemic metrics and outcomes. Carefully articulated goals were enunciated and key benchmarks identified to measure progress. The focus of the reform initiative was located at the Resource Center for Science and Engineering--this Institute operates as a virtual organization within the University System and supersedes the traditional departmental, colleges, and campus academic management structures and has been successful in gaining the attention and endorsement of the upper academic management of the Institution on the merits of its strategic plan and systemic assessment of the educational enterprise. The Center has pioneered a model Institutional Research program that brings together strategic planning, institutional assessment, targeted pilot projects to spearhead reform, and the establishment of policy to allocate infrastructure

and human resources to achieve agreed upon goals.

As a result of this initiative and through careful design of systemic metrics and benchmarks, key weaknesses in the educational pipeline were identified in the form of SMET gatekeeper and bottleneck courses. Pilot projects to reform the system were pioneered.

Evidence was provided to persuade top decision makers of the importance of Institutional Research as the appropriate mechanism to establish policies following a rational approach that results in the improvement of the effectiveness and efficiency of the educational system. While cadres of reform oriented educators were nurtured and supported in the development of pilot projects to reform undergraduate

education. Evaluation of these pilot projects have persuaded CEO's of at least two campuses to scale-up the reform. They have also implemented Faculty Development Programs for the improvement of faculty, teaching/learning skills and methods. At the system level, an Academy for the Improvement of the Middle Management to Support the Educational Reform is being developed.

The reform effort in SMET has spilled over to the area of Teacher Preparation (TP) programs. By joining efforts, the AMP project and the Puerto Rico Statewide Systemic Initiative (PR-SSI) have harnessed a strategic alliance of the schools of Education and Natural Sciences to reform the SMET-TP programs. The assessment methodology of the AMP project described in this paper has been adapted to pioneer a similar educational

reform of TP programs with the active participation of reformed teachers and schools of the PR-SSI.

The Resource Center for Science and Engineering has helped to set a Science and Technology Policy for the Government of Puerto Rico. The Policy calls for the strengthening of the human resources development capacity of the University to meet the challenge of the knowledge economy. The feedback of this Policy will ensure that the commitment of achieving the goal of graduating 4,071 B.Sc. majors, by the year 2001, from Puerto Rican universities will be achieved; a net increase of 138% from the base year of 1991 (1,709 graduates).

This goal should be reached as a result of an increase in the effectiveness of the teaching/learning enterprise and a transformation of the institutional culture at UPR. The University now has as its mission to develop and strengthen its capacities as a research/teaching institution with equal weight given to both components.