ASSESSING THE IMPACT OF CURRICULAR AND INSTRUCTIONAL REFORM -- A MODEL FOR EXAMINING GATEWAY COURSES

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Abstract
Many faculty would like to improve the introductory or “gatekeeper” courses that frequently defeat first-year students, such as English composition, accounting, mathematics, science, and others, depending on the mission of the institution. The mathematics department at The University of Texas at El Paso implemented a Precalculus curricular and instructional initiative to increase the academic success of freshmen. The institutional research and planning center developed an evaluation model to study the effectiveness of the faculty effort. This alternative assessment approach focuses on students who have passed gateway mathematics courses to examine their academic success in the next course in the curricular sequence. Results suggest that the evaluation model provides a comprehensive, objective means to analyze student achievement. The model can serve as a valuable catalyst to assist faculty in assessing their curricular and instructional reform efforts, whatever the subject matter of their gatekeeper courses.

Assessment Background
In the lead editorial for a special issue of Change magazine on teaching and assessment, Marchese points to national data suggesting that the past 15 years of the assessment movement have had only minor impacts on the improvement of student learning. He notes the faculty’s critical role in the improvement of student knowledge and skills:

... faculties, after all, set the curriculum, award degrees, and certify readiness for practice. Their ability — collectively — to produce high-order outcomes for all students is crucial. To do so, as we say, they must have ways of constantly getting smarter and better at bringing the students in their charge to the outcomes they set...

(Marchese, 1999, p. 4)

In a discussion of indicators of curricular quality, Ewell notes the “... pressing demands for curricular consolidation and coherence to achieve greater efficiencies...”

[The] managerial need is for more and better information about how things are working, and how they might be made to work better. If this were not enough, pressures for public disclosure of such information are escalating as funders and accreditors focus increasingly on outcomes and effectiveness. (Ewell, 1999, p. 539)

A 10-year review of assessment and accountability issues quotes a 1993 observation about the role of faculty:

...the single most important outcome of faculty involvement in assessment may be the extent to which the goals and objectives for curricula and courses have been reconceptualized as a result of collective engagement in the assessment process. (Banta, 1999, p. 7)

Thus, faculty face notable challenges in determining if
their innovations have improved student learning. Most faculty have had little assessment or program evaluation training and experience, yet they are expected to address the above issues in addition to their curricular and instructional responsibilities. How can an office of institutional research assume a more proactive and collaborative role in supporting the assessment efforts of innovative faculty?

Because examining semester course grades as a measure of improved student learning is not satisfactory, this article outlines an alternative assessment model focusing on the academic success of introductory or gateway course students in the next course in the curricular sequence. The University of Texas System Louis Stokes Alliance for Minority Participation is part of a nationwide initiative funded by the National Science Foundation (NSF) to increase the number of underrepresented minority students graduating in science, engineering, mathematics, and technology as part of its mandate from Congress. One component involved the development of a model to assess the efficiency and effectiveness of gatekeeper courses at The University of Texas at El Paso (UTEP). Engaging faculty in discussions about expected student outcomes and the kind of information that would be useful to them as they seek to improve student learning and academic achievement is the foundation of the model, which can be applied to any curricular sequence.

Gatekeeper Courses as Barriers

Banta (1999) outlines several critical assessment questions for higher education institutions, including: Are students learning more? Are faculty teaching more effectively? She then describes some universities that are wrestling with issues related to whether students are just taking courses or experiencing an integrated curriculum. For example, a typical finding is inconsistencies in the way in which faculty were teaching course content. Because examining semester course grades as a measure of improved student learning is not satisfactory, this article outlines an alternative assessment model focusing on the academic success of introductory or gateway course students in the next course in the curricular sequence. The University of Texas System Louis Stokes Alliance for Minority Participation is part of a nationwide initiative funded by the National Science Foundation (NSF) to increase the number of underrepresented minority students graduating in science, engineering, mathematics, and technology as part of its mandate from Congress. One component involved the development of a model to assess the efficiency and effectiveness of gatekeeper courses at The University of Texas at El Paso (UTEP). Engaging faculty in discussions about expected student outcomes and the kind of information that would be useful to them as they seek to improve student learning and academic achievement is the foundation of the model, which can be applied to any curricular sequence.

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According to Tobias (1990), college introductory mathematics and science courses have remained competitive, exceedingly difficult, and intimidating primarily because science professors anticipate that the current generation of high school science students is better trained. Therefore, instead of nourishing average students' skills and science interests, college instructors still expect to interact with and teach only the most accomplished students, almost ignoring the needs of potentially good students (e.g., B students). For many first-time college freshmen interested in science and engineering careers, the introductory mathematics and science courses take on a "gatekeeper" role (Tobias, 1992; Van Valkenburg, 1990). These gatekeeper courses frequently block students from progressing into degree programs, thus eliminating students who are judged as lacking the analytical ability to become competent scientists and engineers. The pool of degree program majors and baccalaureate recipients decreases, ensuring a shortage of both scientists and potential faculty members in science, mathematics, engineering, and technology areas.

As a result of such observations, faculty in numerous disciplines, but especially science, have been engaged in debates about the function of their gatekeeper courses. They have attempted to reconceptualize the role of the introductory courses as that of a "gateway" course rather than a barrier or filter. The function of a gateway course should be that of a pump or springboard: to motivate and prepare entering students to succeed in the curricular sequence, thus increasing both the number and quality of students who will major in and graduate from the institution's academic programs. Given the lack of agreement about the function of these introductory courses, faculty who engage in curricular and instructional changes to improve student learning face demanding evaluation questions.

The Literature on Evaluation of Science Curricular and Instructional Reform Efforts

Science curricular and instructional reform literature contains data from a variety of evaluation methods. For example, some assessment efforts reported anecdotal evidence (Coppola, 1995; Magner, 1996). Others proposed effective evaluation methods without providing evaluation data (Daily & Zhang, 1993; Prabhu & Ramarapu, 1994; Seltzer, Hilbert, Robinson, & Swartz, 1996; Willemsen, 1995). In addition, some researchers used student satisfaction ratings of new courses as compared with reformed courses (Johnson & Leonard, 1994; Woods, 1996). An NSF project to update engineering education published a curriculum innovation manual that emphasized the importance of quality improvement, but the manual focused almost entirely on student feedback to improve course content and how it is delivered rather than addressing student learning (SUCCEED Project, 1996).

Others have reported student course retention and failure rates (Felder et al., 1993; Luck & Stephens, 1992; Osborne & Fullilove, 1993; Ratay, 1994). Some evaluation efforts used student course and final examination grades comparing original courses with reformed courses (Davis & McCoullum, 1992; Hershberger & Plantbold, 1994; Johnson, 1995; Lomen, 1992; Penn, 1994; Tidmore, 1994; Woods, 1996). Some studies attempt to incorporate aspects of several of these approaches (Felder, Felder, Mauney, Hamrin, & Dietz, 1995), including analysis of the match between students' expectations and their actual experiences (Johnson & Leonard, 1994). Adelman (1989) published a manual of creative approaches to assessment of undergraduate learning in Biology, Chemistry, Computer Science, Mechanical Engineering, and Physics. Ratcliffe (1993; 1994) developed a coursework cluster analysis model for linking assessments of the general learning of graduating seniors with their previous coursework that can be adapted to examine gatekeeper courses. Evaluation of the Emerging Scholars Program is an example of a systematic approach to examining the
Figure 1
Student Flow through a Gateway Course and the Potential Outcomes
The evidence from evaluations of science and mathematics curricular and instructional reform efforts may be limited in two ways. First, some observers are quick to challenge approaches that compare course grades, questioning whether innovative professors may have eased the academic rigor of the course and/or lowered the standards, thereby fostering grade inflation (Rosen & Klein, 1996). For example, according to Wilson (1997), critics of the Harvard Calculus Model contend that those calculus courses have been “watered down” in an attempt to make Calculus more relevant to undergraduates. Secondly, while student satisfaction ratings of the new courses may offer useful suggestions, they do not provide an objective measure of students’ learning and skills development or prediction of their future academic success. Many of the evaluation case studies may not be generalized and are somewhat removed from faculty concerns about curriculum and instructional innovations and monitoring of student learning in gateway courses. Few offer a systemic approach to or model for the evaluation of curricular and instructional improvement.

**Possible Student Outcomes in a Gateway Course**

To evaluate the impact of curricular or instructional innovations on student learning, faculty have traditionally looked at course grades (i.e., pass rates) as the primary measure of curricular or instructional improvement. Assuming no significant variations in students, two reactions are possible to course grades. A high failure rate may imply high academic standards, or it may indicate curricular and instructional problems. Similarly, an increase in pass rates could be interpreted as the result of lowered standards, or it could reflect a more coherent curriculum and/or improved instructional strategies. The problem in using course grades as the primary indicators is that this approach cannot resolve these issues.

In addition, a primary focus on course pass/fail rates ignores student patterns in terms of withdrawal, requesting an incomplete grade, repetition of the course, and other behaviors that indicate whether the course is achieving its purpose. Using course grades may also fail to distinguish between the academic achievement of students attempting the course for the first time and those repeating it, thus blurring the effects of innovation. See Figure 1 for a flow chart that illustrates the potential outcomes of a student taking a gateway course for the first time and the complexity of attempts to analyze the impact of any curricular and instructional changes:

**Initiating a Dialogue with Faculty about Evaluation of Curricular and Instructional Reform**

Stark et al. (1997) described the need for institutional researchers to work on measures of program effectiveness or efficiency and suggest various strategies to use without reducing faculty autonomy. UTEP designed the ICE$^2$ model (ICE-squared – Indices of Course Efficiency and Effectiveness) for this purpose.

The ICE$^2$ evaluation process begins with department faculty who have identified a gateway course as a barrier.
and, therefore, have decided to undertake some type of departmentally-sponsored innovation. The University’s office of institutional research engages in dialogue with the faculty and/or the chair about the history and context of their innovation and the conceptual base of the ICE$^2$ model as the first step. Faculty identify the targeted gateway course, the next course(s) in the curricular sequence that students are expected to take, and the number of years that cohorts affected by the innovation will be followed. The issues revolve around what is a reasonable amount of time for a gateway course to prepare an entering cohort of students and not on the exceptional cases of individual students or even groups of students. The model recommends 24 months – i.e., the first semester attempted and three long semesters thereafter (see Figure 2). Any longer period suggests that the gateway course is serving as a barrier rather than a springboard into the major or degree program.

Agreement also has to be reached about the baseline data, i.e., performance of former cohorts or retrospective studies, which will be used for comparison purposes to determine whether improvement is occurring. If certain sections of the gateway course are involved in the innovation and others are not, these must also be clearly identified in advance. The model works best when combined with realistic and flexible formative evaluation techniques managed by the gateway course coordinator that provide student feedback to instructors on a regular basis. It also assumes a common exam or assessment process being used by all instructors in the different sections of the gateway course.

It quickly becomes evident that attempting to track the large numbers of students enrolled in different sections of most gateway courses is a formidable task. As faculty accept the premise of success in the next course in the curricular sequence on the first attempt as a valid measure of their improvement efforts, they generally recognize that simply tallying gateway course grades will be insufficient. Thus, the ICE$^2$ model is interesting. However, faculty may also become anxious about instructor evaluations and the possibility of retaliation or censure. Clear direction from the chair about access to section information that might affect faculty accountability is essential. The ICE$^2$ model was not designed to evaluate faculty performance or to target individuals for punishment. Its goal is to support faculty improvement efforts by providing longitudinal and objective measures of curricular and instructional reform outcomes. Therefore, as a general guideline, the Center shares all results (i.e., sections and summaries) with the department chair so as to facilitate departmental discussion and planning, but only summary results with any other interested parties or masked section results for demonstration purposes. See Figure 3 for an illustration of the ICE$^2$ consultation process.

A Case Study: UTEP Faculty Goals for Calculus Curricular and Instructional Reform

Beginning early in the 1990s, a major goal of UTEP has been to improve the introductory or gatekeeper mathematics and sciences courses in its Science and Engineering programs through faculty innovations in curricular and instructional practices. The anticipated outcome is the increased retention and academic success of all freshmen and sophomore students. Changing the
role of these courses from a barrier into one of a “gateway” should also contribute to an increased number of students who persist in Science and Engineering programs and who graduate in a timely fashion. Targeted courses include Precalculus and Calculus, General Biology, General Physics, General Chemistry, and Introduction to Engineering. Drawing on a pilot needs assessment project from the University of Puerto Rico, UTEP explored a variety of ways that its institutional research office could support academic departments that were experimenting with gateway course curricular change and instructional innovation.

Frustrated by the large number of entering students who did not pass Precalculus and Calculus, the chair of the UTEP Department of Mathematical Sciences decided to undertake an extensive curricular and instructional reform effort, including the implementation of Harvard Calculus Reform beginning fall 1994. Simultaneously, a full-time lecturer volunteered to design a modular approach to Precalculus. The chair realized that a longitudinal evaluation model would be required to validate any such initiatives, because colleagues might be quick to challenge improvements in grades as resulting from a watered-down curriculum and/or instructor sympathy. He proposed the radical concept that gateway course curricular and instructional reform could not be evaluated by the course’s pass rates, but rather that the only valid measure would be students’ grades in the next course in the curricular sequence – and that if a gateway course were to be judged effective, the majority of students who completed it should be able to pass the next course in the sequence on the first try.

Given the math department’s challenge of how to evaluate such a premise, the UTEP Center for Institutional Evaluation, Research and Planning began in 1994 to design and pilot the ICE model to study the student outcomes of the Precalculus course. Preliminary results suggest that the model provides a more comprehensive and objective means to analyze student academic progress and, based on informal feedback from academic leaders, it can serve as a valuable catalyst to assist faculty in assessing their curricular and instructional reform efforts.

The University’s math department engaged in three phases of curricular and instructional innovation during several years in an effort to improve student learning in the Precalculus course. Prior to the curricular reform, students had to complete Precalculus I and Precalculus II, each a four semester-credit-hour course, before they proceeded to Calculus I. The Precalculus I pilot four semester-credit-hour course began a new modular approach in fall 1994, with a comprehensive evaluation process that included intensive student and instructor feedback. For the next four years, students were still required to complete another four semester-credit-hour course, Precalculus II, before they could proceed to Calculus I. In fall 1998, the math department created a new Precalculus course with the reform modular curriculum by compressing the former two courses that were four semester-credit-hours each into one five semester-credit-hour course. The University began piloting a cluster course mechanism for pre-engineering and prescience majors in fall 1995. Selected numbers of students were enrolled in the same sections of Precalculus I, English, and an engineering or science course to encourage the development of academic peer support groups. This brief historical description illustrates the context and complexity of such faculty innovations that must be documented and understood in order to interpret results from the ICE model.

**Gateway Course Efficiency: Students Survived the First Course of the Curricular Sequence**

The ICE index, developed at the University of Puerto Rico, is the first indicator in the ICE model. It serves as a measure of a gateway course’s efficiency — that is, it takes into consideration the pattern of unsuccessful attempts, incomplete grades, withdrawals, and repetition that often characterize many such courses, while tracking students’ ultimate outcome in the targeted course. The index demonstrates the progress of cohorts of first-time takers in the Precalculus course during a 24-month period (the initial attempt, plus three additional long semesters):

- the percent of first-time takers who pass the gateway course on the initial attempt;
- the percent of gateway course first-time takers who pass within the two-year period;
- the percent of gateway course first-time takers who cannot complete the course within that period; and
- the total number and percent of successful outcomes (all gateway course students from the initial cohort of first-time takers who pass with a grade of C or higher, including both students who succeed on their initial attempt at the course and students who eventually succeed within the two-year period).

The ideal ICE index for a gateway course would be a low of 1.0, indicating that every student who registered for the course passed with a grade of A, B, or C on the first attempt. It thus serves as an indirect measure of cost-efficiency for a department chair. As ICE rises, it indicates that the course requires increasingly greater institutional resources, as well as student investment of time and funds.

The index provides a department chair with one objective measure to reflect the true costs (faculty salaries, student attrition, faculty discouragement with failures and incomplete grades, loss of potential majors to programs that require the gateway course, etc.) of the gateway course. Calculations of the ICE index illustrate the traps that students fall into which may tend to drive them away.
from the gateway course, thus eliminating them as potential majors in fields that require the course. UTEP Precalculus data in Table 1 illustrate this first phase of the model, and Figures 4 and 5 graph the outcomes and ICE index.

**Gateway Course Effectiveness: Students Learned What They Need to Know in the First Course of the Curricular Sequence**

The ICE² (ICE-squared) index is the second indicator in the model. It serves a different purpose, in that it provides a measure of the gateway course's effectiveness – defined as the student’s success in the next course in the curricular sequence. Therefore, the index follows the original ICE index cohorts during the same two-year period into the course that the faculty has identified as the appropriate next step in their degree plan. ICE² index tracks the Phase I succeeders (i.e., all first-time takers who eventually passed the gateway course during the 24-month period) to determine if the course is achieving its specified purpose, i.e., to prepare students to pass the next course in the curricular sequence. The index examines:

- the percent of first-time takers who passed the gateway course and enrolled in the next course in the curricular sequence – an indicator of whether capable students are continuing in the major as a result of the gateway course experience;

- the percent of gateway course successful first-time takers who pass the next course in the curricular sequence on the initial attempt: an indicator of whether the gateway course prepares students with the knowledge and skills needed for the next course in the curricular sequence; and

- the total number of gateway course successful first-time takers who pass the next course within the two-year period: an indicator of the potential pool of students for majors that require the gateway course and the next course in the curricular sequence for admission to their degree programs.

An ICE² index of 1.0 for the targeted gateway course is ideal, indicating that every student who

### Table 1

**Gateway Course Curricular and Instructional Reform: A Two-Year Report on Course Efficiency—Performance in a Precalculus by Cohorts of First-Time Students**

<table>
<thead>
<tr>
<th>Cohorts of First-Time Precalculus Students:</th>
<th>Fall 1993</th>
<th>Fall 1994</th>
<th>Fall 1995</th>
<th>Fall 1996</th>
<th>Fall 1997</th>
<th>Fall 1998*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of first-time takers</td>
<td>396</td>
<td>438</td>
<td>388</td>
<td>387</td>
<td>369</td>
<td>371</td>
</tr>
<tr>
<td>First-time takers who passed Precalculus on the first attempt</td>
<td>14.9% (59)</td>
<td>32.6% (143)</td>
<td>36.9% (143)</td>
<td>49.9% (193)</td>
<td>36.3% (134)</td>
<td>38.0% (141)</td>
</tr>
<tr>
<td>Additional students in the first-time cohort who eventually passed Precalculus during the two-year period</td>
<td>29.8% (118)</td>
<td>28.1% (123)</td>
<td>28.6% (111)</td>
<td>23.5% (91)</td>
<td>23.3% (86)</td>
<td>29.9% (111)</td>
</tr>
<tr>
<td>Total of students who had successful Precalculus outcomes (grade of C or above)</td>
<td>44.7% (177)</td>
<td>60.7% (266)</td>
<td>65.5% (254)</td>
<td>73.4% (284)</td>
<td>59.6% (220)</td>
<td>67.9% (252)</td>
</tr>
<tr>
<td>ICE: An Indicator of Course Efficiency</td>
<td>3.80</td>
<td>2.61</td>
<td>2.35</td>
<td>1.98</td>
<td>2.44</td>
<td>2.28</td>
</tr>
</tbody>
</table>

**Note:**
- ICE = the average number of attempts it takes a cohort of students to pass the gateway course
  - **Numerator** = total number of attempts by a cohort of first-time students to pass the gateway course during a 24-month period
  - **Denominator** = the number of successful attempts (C or better)
- **ICE index:** The closer to 1.0, the more efficient the course
- Two years: A fall cohort of students who enrolled in the gateway course for the first-time is tracked for a 24-month period (the initial attempt, plus three additional long semesters and the two summer semesters).
- Incomplete analysis: lacks results for Summer 2000 semester

**Figure 4**

**ICE: Performance in Precalculus by Six Cohorts of First-Time Students during the Subsequent Two Years**

- Cohort students who were unable to pass Precalculus during the two-year period
- Cohort students who did not pass Precalculus on the first attempt, but eventually passed during the two-year period
- Cohort students who passed Precalculus on the first attempt

*Incomplete analysis: lacks results for Summer 2000*
Figure 5
ICE: Index of Course Efficiency — Performance in Precalculus by First-Time Takers

|                  | Fall 93 | Fall 94 | Fall 95 | Fall 96 | Fall 97 | Fall 98*
|------------------|---------|---------|---------|---------|---------|---------
| Total number of successful first-time Precalculus students (the potential pool for majors) | 177     | 266     | 254     | 284     | 220     | 252     |
| Successful Precalculus students who enrolled in Calculus I (those who persist in the major) | 34.5%   | 44.4%   | 42.1%   | 41.9%   | 50.9%   | 64.3%   |
| Students who passed Calculus I on the first attempt (indicator of improvement in the gateway course) | 65.6%   | 55.1%   | 68.2%   | 60.5%   | 50.9%   | 50.6%   |
| Students who eventually passed Calculus during the two-year period (the pool for majors/degree programs) | 77.0%   | 79.7%   | 77.6%   | 75.6%   | 70.5%   | 66.7%   |
| ICE2: An Indicator of Course Effectiveness — for each cohort of successful first-time Precalculus students who enrolled in Calculus I | .66     | .55     | .68     | .61     | .51     | .51     |

ICE2 = success rate on the first attempt to pass the next course in the curricular sequence by those cohort students who passed the gateway course and subsequently enrolled in the second course during a 24-month period.

- **Numerator** = The number of students in the cohort who passed the gateway course and then enrolled in the second course of the curricular sequence during a 24-month period and who passed that second course on the first attempt.
- **Denominator** = The number of all cohort students who attempted the second course.

ICE index: The closer to 1.0, the more efficient the course.

|   | Fall 1994 | Fall 1995 | Fall 1996 | Fall 1997 | Fall 1998*
|---|-----------|-----------|-----------|-----------|-----------
| 0 | 100       | 75        | 50        | 25        | 0         |
| 1 | 75        | 50        | 25        | 0         | 0         |
| 2 | 50        | 25        | 0         | 0         | 0         |
| 3 | 25        | 0         | 0         | 0         | 0         |
| 4 | 0         | 0         | 0         | 0         | 0         |

*Incomplete analysis: lacks results for Summer 2000

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Results

The various elements of the ICE2 model demonstrate the strides being made by the UTEP Precalculus program, which has been involved in an extensive curricular and instructional improvement since fall 1994. As noted above, the mathematics department identified its target course, decided on a particular curricular approach, developed some innovative instructional approaches, and incorporated an on-going formative evaluation process whereby students regularly provide feedback to instructors, and the coordinator compares student progress across sections. The ICE2 model, therefore, is an essential component of a major departmental curricular and instructional reform effort.5

Curricular review by the Precalculus instructors and by the department chair incorporates a wide variety of formative evaluation information and the objective indices of progress offered by the ICE2 model. For example, based on the ICE index results, the faculty developed such confidence in the new approach that they decided to restructure the Precalculus curriculum and to eliminate the Precalculus II course. Although enrollment in Precalculus I declined during the six-year period, the changes implemented increased the number and percentage of students completing the first Precalculus course, going on to Calculus I, and ultimately succeeding in the next course, thus increasing the pool of science, engineering, and mathematics majors.
Results for the ICE² index showed slight improvement in the third year, but the ICE² index has actually declined since the base year of 1993. Feedback from the Precalculus coordinator suggests that the primary explanation for the low ICE² is the 166 percent increase in the number of students taking Calculus I by the sixth year of the Precalculus reform period and the large number of modular sections added the fifth year, which resulted in insufficient time for training of newly recruited instructors. She believes that the curriculum, instructor orientation, and section feedback processes are stabilizing. The almost complete data for the fall 1998 cohort appear to partially support this explanation in terms of positive Precalculus outcomes, the highest enrollment in Calculus I during the study, and the growing number of students ultimately passing that course within the two-year period. The ICE² measure, which remains at 0.51, however, highlights that faculty responsible for the two courses should continue to improve articulation and alignment issues, in terms of curricular content, instructor practices, and assessment methods.

**Discussion**

An NSF workshop on indicators of success in college Science and Engineering education quoted in 1998 Dr. Manuel Gómez, Director of the Puerto Rican Louis Stokes Alliance for Minority Participation:

[He stated that] to bring about effective institutionwide use of assessment data, one must approach each stakeholder group in terms of its values and needs... Only when confronted with data on their own students... will faculty buy into the conclusions and start to change their department... He therefore urged reformers to structure assessment and evaluation
information intended for administrators in ways that clearly communicate how educational change is affecting the system . . . Gómez argued that while change makers at the classroom and departmental level are essential, isolated individual efforts ultimately will be rejected by the institution if institutional leaders do not understand the cumulative value of their efforts. (Miliar, 1998, pp. 28-29)

The two components of the ICE\(^2\) model provide valuable information for departmental planning, both to department chairs and to faculty. The two indices can serve as longitudinal measures of the benefits of curricular and/or instructional change. The innovative work done at the University of Puerto Rico on the ICE index can be replicated to identify any course, not just the gateway courses, that may be serving as barriers in curricular sequences and degree plans. The information generated from calculation of the ICE index illustrates differences of efficiency among sections and can challenge faculty to discuss among themselves why some sections generate such high levels of student repetition and withdrawals. If arguments arise about high academic standards in the gateway courses, the UTEP ICE\(^2\) index encourages more objective discussions of introductory course effectiveness and transferable student knowledge and skills. Such dialogue should promote a more carefully aligned curriculum and a more objective arena for instructor improvement and student achievement.

In addition, the flexibility of the ICE\(^2\) model offers important advantages. Note that the model described here encompasses two years (four long and two summer semesters) on the assumption that if cohorts of first-time takers cannot complete the gateway course and the next course in the curricular sequence within 24 months, they have little hope of success in the degree program. Yet if the characteristics of an institution or its student body (e.g., commuters, studying part-time, working more than 20 hours per week, single parents, etc.) indicate that entering students need more time to complete a curricular sequence, the ICE\(^2\) analysis period could be expanded from four semesters to five or six. In UTEP’s case study, the department used a modular instructional program that allowed students more than one semester to complete the gateway courses and assigned them a grade of P if they chose that option. The model was able to analyze the impact of that approach.

The model also allows a department chair to compare if appropriate: a) targeted or pilot sections involved in curricular or instructional reform with traditional sections, b) the performance of different groups of students (e.g., the subsequent success of students who earn a grade of C in comparison to those with As and Bs), c) what patterns have occurred with respect to student withdrawals or incomplete grades, and d) widely varying performance of different cohorts of students that might be a result of extraneous factors. UTEP’s math department has been engaged in several years of dramatic change in both the Precalculus course and the Calculus sequence. This makes evaluation of the impact of curricular and/or instructional change quite challenging. The ICE\(^2\) model provides a valuable framework to use in illuminating the longitudinal effects of different interventions.

Another potential application of the ICE\(^2\) model involves examining the outcomes of a gateway course that feeds more than one curricular sequence. For example, the Introductory Biology course typically enrolls students who are interested in becoming Biology majors and others focused on the health professions, as well as students who may simply be looking for a science course to complete core curriculum requirements.

**Conclusion**

Banta (1994) questions, “Are We Making a Difference in Student Learning?” She emphasizes that “carefully planned longitudinal studies are needed to produce convincing evidence of change in students’ knowledge and skills over time, and few institutions have invested the time and money necessary to conduct such studies” (Banta, 1999, p. 82). She also notes problems associated with the use of commercial tests of student achievement, including their limited assessment of the content that faculty associate with general education. Leaders of the Carnegie Foundation for the Advancement of Teaching conclude a discussion of the scholarship of teaching by proposing that campuses should think about redefining the work of their institutional research offices to foster research that “asks much tougher, more central questions: What are students really learning? What do they understand deeply?... How does our teaching affect that learning, and how might it do so more effectively? (Hutchings & Shulman, 1999, p. 15).

In this spirit, UTEP has demonstrated how the institutional research office can work in partnership with an innovative academic department to create a model that is especially relevant for gateway courses and other curricular sequences. Institutions that are concerned about improving freshmen retention rates, increasing the number of students who enter fields with challenging gateway courses, raising graduation rates, and/or demonstrating that their graduates have attained specific knowledge and skills should find the ICE\(^2\) model to be useful.

Additional information about the ICE\(^2\) model and specific information about calculations of the two indices is available at [http://ampvi.utep.edu](http://ampvi.utep.edu).
Endnotes

1 Partial funding for the development of the evaluation model described here came from the National Science Foundation’s Louis Stokes Alliance for Minority Participation program (NSF grant #HRD 92551660).

2 Andrade directs the Center for Institutional Evaluation, Research and Planning at The University of Texas at El Paso. Dejan Suskavcevic was the Research Assistant in the Center who developed the programming and technical specifications for the model; pilot programming was done by Elizabeth Sánchez. Graduate student interns who assisted with the review of the literature included Delia Hernández, Cathe Lester, and Candace Rutt. Constructive criticism came from Evaluation Task Force members of The University of Texas System Louis Stokes Alliance for Minority Participation and from participants at the 1997 conference of the Texas Association for Institutional Research, where an early version of the model was presented. The author expresses her deep appreciation to all.

3 Since the late 1980s, the National Science Foundation (NSF) has sponsored a national debate about the shortage of scientists, mathematicians, engineers, and technicians who are U.S. citizens. Extensive discussions about curricular issues, instructional practices, the amount of information instructors are expected to cover, and what kinds of student outcomes should be expected in gatekeeper courses have been supported. The Louis Stokes Alliance for Minority Participation (LS-AMP) was created as part of the effort to increase the number of under-represented minority students who graduate with SMET degrees. The University of Texas LS-AMP partnership of universities and community colleges invested considerable effort in improving their science and mathematics gatekeeper courses to help increase the success and retention of freshmen and sophomore students. NSF defines under-represented minority students as individuals of African-American, Hispanic, or Native American origin.

4 Ana C. Piñero, “Measuring the Effectiveness and Efficiency of SMET Programs: The Index of Course Efficiency (ICE)”. A presentation to Historically Black Colleges and Universities representatives, National Science Foundation, March 10, 2000. For more information, contact a_pinero@upr1.upr.clu.edu.

5 Dr. Simon Bernau, Dean of the School of Science at California State Polytechnic University-Pomona, was chair of the UTEP Department of Mathematical Sciences at the time. Dr. Nancy Marcus designed and implemented the UTEP Precalculus modular program and continues to coordinate it. The author expresses her appreciation to them both for their vision of UTEP student success and for their support in developing this evaluation model.

6 The UTEP Precalculus curricular project is coordinated by Dr. Nancy Marcus. For more information on the curricular and instructional approach, visit the Web site at www.math.utep.edu/classes/precalculus.

7 The development of the Web site of the Virtual Center for Formative Evaluation was funded by NSF and sponsored by The University of Texas System Louis Stokes Alliance for Minority Participation. It is administered by the UTEP Center for Institutional Evaluation, Research and Planning.
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