The Use of Metrics to Drive Undergraduate STEM Education Reform: The Puerto Rico-LSAMP Experience

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Prepared by:

Davis Consulting, Inc.
Evaluation Team

Dr. Ana C. Piñero
UPR Resource Center for Science and Engineering

A Retrospective Cohort Study of Science, Technology, Engineering, and Mathematics Students

How and Why It Was Done (An Introduction)

In September 2001, the National Science Foundation (NSF) asked the Puerto Rico Louis Stokes Alliance for Minority Participation (PR-LSAMP) to share with other LSAMP grantees, the knowledge and expertise gained during Phase I and Phase II of the project in the use of metrics to drive reform initiatives. The result is this Manual of Metrics, that we hope would assist the different LSAMP institutions identify and use metrics for benchmarking, to measure progress, and to design models and strategies to improve student performance and ultimately increase the number of students that enter and complete graduate studies in STEM fields.

Background

The Puerto Rico Louis Stokes Alliance for Minority Participation (PR-LSAMP), initiated in 1991, is an alliance of the major higher education institutions in Puerto Rico with the goal of increasing the number of students that obtains a baccalaureate degree in science, mathematics, engineering, and technology (STEM) fields. During the past eleven years (Phase I and Phase II), PR-LSAMP institutions have increased by 81% the number of BS degrees awarded, from 1,709 in 1991 to 3,094 in 2002. The undergraduate STEM enrollment of 26,524 students as of the Fall of 2001 constituted about four-fifths of all STEM undergraduate students in Puerto Rico in a truly statewide program. This population is 98+% Hispanic, two-thirds first generation, and over 70% low-income. Although Puerto Rico makes up only 13% of the U.S. Hispanic population, PR-LSAMP institutions conferred in the Year 2000, 2,771 BS degrees in STEM, 22% of the 12,835 conferred nationally to Hispanics that year (2000 NSF Division of Science Resource Studies data). This performance makes PR-LSAMP institutions a potent resource for producing STEM graduates.

Since its inception, PR-LSAMP sought to develop an effective assessment program to:

- meet reporting requirements
- to evaluate the success of our program activities
- to document progress to support requests for continued funding, and
- to provide effective formative evaluation.

Using the formative evaluation data, PR-LSAMP staff worked with the alliance's partners to maximize the benefits of successful activities and implement new activities or modifications to constantly improve the program and the results for each institution's STEM population. To accomplish these assessment objectives, the PR-LSAMP management worked closely with an external evaluation team to develop the necessary metrics to meet these objectives.

The external evaluators were presented with a number of issues relating to the task of conducting research and analyzing the STEM students and programs of PR-LSAMP institutions to produce detailed analytical data in addition to the basic data of number of graduates. We recognized that many alternatives are available to institutional researchers and external evaluators for assessment. In order to obtain assessment that was both feasible to conduct and useful to PR-LSAMP, it was determined to use the mechanism of **a retrospective cohort study**. In order to help those with similar interests, this manual provides a step-by-step description of the process of developing a retrospective cohort study and employing some standard and innovative metrics as part of a broader study.

What Is a Retrospective Cohort Study, and What Are Its Advantages?

A ***cohort study*** in general is a mechanism for analyzing the behavior of a system. It deals with a coherent group of individuals that:

- enters a system
- receives treatment, and
- exits as intended or via an "escape" route

In the academic world "the escape route" is most commonly a "drop out," whether by failure to prosper or by transfer to a more desirable institution, or a change of program, such as from STEM to non-STEM. The characteristics of the individuals who take an escape route may be quite different, one from another. The two extremes are students who cannot manage their academic challenges and leave the university environment altogether on the one hand, and those who do well (even outstandingly) but are dissatisfied with the university where they first matriculated and transfer to one that they prefer on the other.

> A cohort may also consist of a group that undergoes similar experiences even when they do not participate in these experiences as part of a formal, unified program. A cohort study follows or "tracks" this specific group of individuals. In the current case the cohort of interest consists of students of science, technology, engineering or mathematics (STEM) during their undergraduate careers (the "system" or "treatment").

Although a ***prospective cohort study*** is often used for medical and sociological or anthropological issues, and has undeniable advantages, it also has significant drawbacks. It is time-consuming, costly, and risky for the evaluators, if they lose too many members of the cohort during the experiences.

A ***retrospective cohort study***, in contrast to a prospective study, does not require identifying the members of the cohort at the beginning of a process and following them through their experiences prospectively. All that you have to do is *select* from a pre-existing group, whose outcomes are already decided, working from the pool of records (transcripts in this case) available to the evaluators. A retrospective study thus has some limitations, but it is much more efficient and cost-effective since it can use existing records and be completed in a short time. Naturally, analysis is limited to the data available from existing records, but in the increasingly assessment-conscious academic world, more data is becoming available to evaluators every day.

Data Used in the Retrospective Cohort Study, and Information Generated by Its Analysis

A higher education institution collects a great deal of basic data in a reliable format, including items such as course registration, course completions and grades, graduation data, and related data such as the times when these events took place. The Registrar keeps these records for each student and can supply copies for research purposes with personal identifying information expunged. This permits evaluators to conduct investigations that identify problem courses, quantify their adverse effect on student success, and even calculate their cost to the institutions in resources required to produce satisfactory student outcomes, as described below in this report. The program and individual partners can then employ this information to improve teaching and support activities for STEM students. By comparing these data with comparable data from other cohorts after program activities, evaluators can document the details of program impact. This is illustrated below in a comparative table on key indices (discussed later in this manual).

Other information gleaned from this particular cohort study included changes in careers and “flows” of students through the system. In this study, the evaluators identified roughly at what point in their academic careers students made program changes, if any. This information clarified the issue of how many “successes” and “failures” there are, and refined the question of what may constitute a success or failure for a particular academic management purpose.

Gatekeepers and Bottlenecks: Qualitative and Quantitative Metrics

These data identify more reliably the obstacles to timely completion of the intended degree, confirming the hypothesis of the existence of "gatekeeper" and "bottleneck" courses and indicating the direction of further study. A “gatekeeper” course is one that presents substantial difficulties for significant numbers of students attempting to embark on a particular program of study. A “bottleneck” course is one that presents difficulties for students at an advanced stage of a program of study that delay or prevent completion of the program.

In addition to this qualitative analysis--identifying courses that fall into the gatekeeper or bottleneck category, the evaluators were able to obtain important quantitative information as well from their analysis. Quantitative information included:

- the *relative* ease or difficulty for students of successfully repeating problem courses,
- the *relative* impact of the problem courses, and
- the “cost” to the institution (and to students) of these problem courses.

These data indicated areas for further study, such as identifying the different techniques used by institutions in dealing with problem courses and judging the degree of success of these techniques.

This evaluation model was applied to the member institutions of the PR-LSAMP alliance during Phase I and Phase II of the project. The results gave the evaluators data on which to base observations and conclusions, and from which to develop hypotheses to explain the phenomena, which may be investigated further in other studies, and which may be acted on by administrators and faculty.

Methodology of the Study

To conduct this **retrospective cohort study**, each institution made available a copy of individual transcripts of students in the STEM fields according to criteria specified by PR-LSAMP, identified only by number. These transcripts had been selected at random from among all students who entered the university with the declared intention of studying in STEM fields during the years indicated. The number of transcripts was determined by the evaluators. The round number 100 was chosen when the group was sufficiently large to permit selection of a random sample of 100. With smaller populations, or those only slightly larger than 100, the universe of all transcripts which met the criteria was tabulated.

The evaluators then used this material to "track" students from entrance to final disposition at the institution where they originally matriculated, according to the data on the records. (This evaluation was generally limited to activity at the institution because few had post-departure data on students who left before graduation).

The data came from records of individuals entering as first-time students, and were, to the extent feasible, selected from a sufficiently distant year to give adequate time for the students in the cohort to graduate or make some other final disposition of their undergraduate academic careers.

Recording and Tabulating the Data: Four Steps to a Retrospective Cohort Study

Two types of data are of interest:

(1) global data on student performance at the institution, such as how many students graduate and how long it takes them to complete their degree, and
(2) data on specific courses that constitute roadblocks on the student road to graduation and related descriptive data on those courses and their impact.

Step 1: Selecting the sample

For both types of evaluation, it is necessary to have a single meaningful sample--the cohort. To obtain this sample:

- request from the Registrar copies of the transcripts of a predetermined sample (i.e., 100 randomly selected students per program or the total population when less than 100) who fit the criteria of the study, expunging any personal identification material from the copy. As in the example used extensively in this manual to illustrate the metrics, the cohort consisted of first-time, full-time students entering in the fall of 1990 who were admitted in Electrical Engineering. Depending on the admissions policies of the institution (declaring a major) the cohort may consist of those with a preference for a specified major, or who subsequently declared that major at their first opportunity (if the institution does not admit by major).

- make sure to set the entrance date sufficiently far in the past to allow for resolution of their academic career, remembering that today's students may take up to seven years to graduate in STEM fields.

Step 2: Extracting the data from the transcripts and making tabulations for global analysis: Graduation Rates and Times and Attrition and Retention

Decide what data to record, and have reliable workers do it manually (assuming the records are not available in digital form). See the sample report (and the commentary below) for the kind of data we thought likely to be meaningful.

Step 2 involves three stages:

- Stage A: extracting and recording data on the final disposition of the students,
- Stage B: tabulating the data for graduation rate and time to graduate, and
- Stage C: tabulating the data for attrition and retention rates.

Step 2- Stage A - The data recorders were first asked to note the Final Disposition of the Student: graduation date and status at time of graduation (major, credits completed, average in major, and GPA), or year leaving and average in major and GPA and credits completed at time of leaving. See **Table 1 - Worksheet: Graduation Rates and Times, with Attrition and Retention Data,** presented in the following page. This is a worksheet that is not presented in the final report prepared for the institution. This Worksheet illustrates the procedure, for example,

- the record of Student #1 shows that his/her field of study was Electrical Engineering, that the last semester matriculated was June 1996, that he/she had been matriculated for a total of just over six years, and had accumulated 168 credits with a GPA of 3.24. The last semester registered coincides with the graduation rate.

- Student #4, the first one in the cohort who did not graduate, had completed 159 of the 168 credits needed to graduate, but may be missing some specific requirements in addition to the number of credits needed. With a GPA of 2.56 and presumably very few credits to complete, this student is considered likely to graduate in the near future.

- Student #12 is one of only two in the cohort who did not graduate and are not still at the institution. After five years of study, and 24 credits short of graduation (assuming all other requirements were met), this student dropped out of the institution in good standing, but with only a modest GPA of 2.46.

Some elements of the individual or group profile may be deduced or speculated based on the data collected. Most of the students in this cohort appear to be pursing their degree in traditional fashion. The institution has been quite successful in retaining students, although it appears that Student #12 could have been retained and graduated with some additional effort/assistance. The other student who dropped out appears unlikely to have been salvageable for a STEM career, although he/she may have been successful in another major. (This institution's admission's requirements are high enough to ensure sufficient potential for graduation in some field.)

TABLE #1: WORSHEET GRADUATION RATES AND TIMES WITH ATTRITION AND RETENTION DATA

Stu-dent	Program of Admission	Last Semester	Years of Study	Credits Attempted	Credits Completed	GPA	Grad. Date	Major Field of Degree	Still at Institution?
1	Elect. Eng.	JUN 96	6.1	174	168	3.24	JUN 96	BS ELECT ENG	
2		MAY 95	5	177	171	2.93	MAY 95	BS ELECT ENG	
3		MAY 96	6	158	168	3.42	MAY 96	BS ELECT ENG	
4		JUN 96	6.1	180	159	2.56			YES
5		JUN 95	5.1	174	168	3.53	JUN 95	BS ELECT ENG	
6		MAY 96	6	180	171	3.02	MAY 96	BS ELECT ENG	
7		MAY 95	5	177	171	2.99	MAY 95	BS ELECT ENG	
8		DEC 95	5.5	183	168	2.73	DEC 95	BS ELECT ENG	
9		MAY 95	5	186	171	2.84	MAY 95	BS ELECT ENG	
10		MAY 96	6	180	168	2.63	MAY 96	BS ELECT ENG	
11		DEC 95	5.5	183	171	2.74	DEC 95	BS ELECT ENG	
12		MAY 95	5	159	144	2.46			NO
13		JUN 95	5.1	174	168	3.40	JUN 95	BS ELECT ENG	
14		DEC 95	5.5	177	168	3.28	DEC 95	BS ELECT ENG	
15		MAY 96	6	195	171	2.83	MAY 96	BS ELECT ENG	
16		MAY 96	6	183	168	3.02	MAY 96	BS ELECT ENG	
17		DEC 95	5.5	177	168	3.62	DEC 95	BS ELECT ENG	
18		JUN 95	5.1	183	174	3.07	JUN 95	BS ELECT ENG	
19		DEC 94	4.5	150	72	1.81			NO
20		JUN 96	6.1	180	156	2.83			YES
21		MAY 95	5	180	174	2.32	MAY 95	BS ELECT ENG	
22		MAY 96	6	183	168	2.65	MAY 96	BS ELECT ENG	
23		MAY 96	6	180	168	2.78	MAY 96	BS ELECT ENG	
24		JUN 96	6.1	177	159	3.13			YES
25		MAY 95	5	177	168	3.14	MAY 95	BS ELECT ENG	

Step 2 - Stage B - To tabulate the data for graduation rate and time to graduate, the data recorders use the transcripts (coded by program and numbered), and make a count of several items:

- the number of members of the cohort who graduated,
- the status (GPA and credits accumulated) of members who left before graduating or at graduation,
- date of graduation or leaving,
- length of time at the institution before graduation or leaving,
- program of graduation, and
- input into the cohort from transfers.

The evaluators may then convert these results into tables for easy assimilation in a chart like the ones presented in tables 2 to 4. **Table 2 – Engineering Sample (1990-91 Cohort) Graduation Rates and Time to Graduate,** includes *tabulated* data based on individual data from Table 1. Table 2 is a summary of performance of segments and the total sample cohort in regard to a number of aspects:

- the graduation rate of each major and of the STEM population of the institution as a whole, based on the sample cohort
- the average time it took the members of the sample cohort to graduate, for actual graduates
- the potential graduation rate, based on a count of the members of the sample cohort still in the system who have not graduated but are still matriculated and in good standing
- the average graduation time taking into account potential graduates, and
- the sample size

Table 2 includes the number of cases in the sample with the graduation rate, including the number who graduated and the percentage of graduates for each major. It includes the average time to graduate for each cohort as well as the potential graduation rate, assuming those still at the institution in good standing and making satisfactory academic progress will indeed graduate. A rough estimate of the additional time remaining was added to their current tenure (based on the rate of progress, usually one or two semesters) as well as the average time to graduate for actual graduates.

This group comprised several engineering fields, all numbering 25, so that all of the sub-sets were completely represented in this aggregate number. **The STEM graduation rate is the rate of graduation *in STEM* at the institution of the entire matriculating cohort**. It makes no allowances for students likely to graduate, graduated or likely to graduate in non-STEM fields, or likely to have graduated or to graduate in a STEM or non-STEM field at another institution ("brain drain" students). This sector was minuscule to non-existent at the particular institution in question, but significant at many other institutions studied. The same calculations were used for both actual and projected graduates.

Table 2

Engineering Sample (1990-91 Cohort) Graduation Rates and Times

Program	Chem. Eng.	Civil Eng.	Comp. Eng.	**Elec. Eng.**	Ind. Eng.	Mech. Eng.	Total
Graduation Rate, B.S.E.	15 (60%)	8 (32%)	6 (24%)	**20 (80%)**	13 (52%)	13 (52%)	--
Average Time to Graduate	5.3 years	5.8 years	5.2 years	**5.5 years**	5.5 years	5.5 years	--
Grad. Rate B.S.E./B.S. in other STEM program	--	2 (8%)	4 (16%)	**--**	2 (8%)	1 (4%)	--
Average Time to Graduate	--	5.0 years	5.3 years	**--**	5.8 years	6.0 years	--
Combined Graduation Rate, STEM	15 (60%)	10 (40%)	10 (40%)	**20 (80%)**	15 (60%)	14 (56%)	84 (56%)
Combined Average Time to Graduate (STEM)	5.3 years	5.6 years	5.2 years	**5.5 years**	5.6 years	5.5 years	5.5 years
Non-STEM Graduation Rate	1 (4%)	1 (4%)	--	**--**	1 (4%)	--	3 (2%)
Non-STEM Avg. Time to Graduate	6.0 years	5.1 years	--	**--**	6.0 years	--	5.7 years
Population/Sample Size	25	25	25	**25**	25	25	150

Of those who had graduated at the time the transcripts were provided, the total number of years (for incomplete years counting a single semester as a 0.5 year and a summer as 0.1 year) was summed and divided by the number of graduates. In the electrical engineering cohort, three students in addition to the 20 who had already graduated were still at the institution in good standing and considered likely to graduate, raising the potential graduation rate to 23, which constitutes a very high 92% total likely graduation rate (see **Table 3 Engineering Sample (1990-91 Cohort) Students Still at Institution – Potential Graduates**). The time estimated for completion of degrees by those who had not actually done so at the time was factored into the total time to graduate along with those who had graduated, and then divided by the total number of both graduates and likely graduates. This gave a composite average time to graduate for electrical engineering students of 5.5 years. The non-STEM graduation rate was slightly longer, 5.7 years, consisting of only three students and none from the Electrical Engineering cohort.

From the data in the set of cases for electrical engineering students (col. 4 in boldface), the tabulation revealed an 80% rate of graduation, with an average time at the institution for graduates of 5.5 years, with an essentially unchanged estimated average time to graduate as, taking into account those still at the institution and likely to graduate, as explained above. Those still at the institution and likely to graduate have only 6-12 credits to complete. The sample size of 25 is given in the last row.

Table 4 Departures STEM Fields, shows that of those who left one had a GPA between 2.00 and 2.69. The other was considered a “drop out” since his/her average was below 2.00, and he/she had accumulated only 72 credits in 4.5 years. Table 4 contains cohorts representing all engineering programs. The aggregate of these programs (the total column), do not show a large number of students leaving, either in good standing or with a poor prognosis (17% total).

Table 3
Engineering Sample (1990-91 Cohort)
Students Still at Institution (May/Summer 1996)
Potential Graduates

Program	**Chem. Eng.**	**Civil Eng.**	**Comp. Eng.**	**Elec. Eng.**	**Ind. Eng.**	**Mech. Eng.**	**Total**
Very Positive Prognosis (GPA > 2.7)	1 (4%)	2 (8%)	4 (16%)	**2 (8%)**	1 (4%)	4 (16%)	14 (9.3%)
Positive Prognosis (GPA 2.00 - 2.69)	6 (24%)	6 (24%)	4 (16%)	**1 (4%)**	1 (4%)	4 (16%)	22 (14.7%)
Poor Prognosis (GPA < 2.0)	--	--	--	**--**	1 (4%)	--	1 (0.7%)
Population Size	25	25	25	**25**	25	25	150

Table 4
Engineering Sample (1990-91 Cohort)
Departures STEM Fields

Program	Chem. Eng.	Civil Eng.	Comp. Eng.	**Elec. Eng.**	Ind. Eng.	Mech. Eng.	Total
Positive Prognosis (GPA > 2.7)	--	(2 (8%)	1 (4%)	**--**	--	--	3 (2%)
Avg. Time at Institution	--	2.6 years	4.5 years	**--**	--	--	3.2 years
Moderate Prognosis (GPA 2.00 - 2.69)	--	2 (8%)	3 (12%)	**1 (4%)**	4 (16%)	--	10 (6.7%)
Avg. Time at Institution	--	2.0 years)	4.3 years	**5.0 years**	2.5 years	--	3.2 years
Poor Prognosis (GPA < 2.0)	2 (8%)	2 (8%)	3 (12%)	**1 (4%)**	2 (8%)	3 (12%)	13 (8.7%)
Avg. Time at Institution	1.0 years	3.3 years	1.5 years	**4.5 years**	0.8 years	1.2 years	1.8 years
Population/Sample Size	25	25	25	**25**	25	25	150

Step 2 - Stage C - A more detailed breakdown of the performance of students is presented in a final chart such as the one shown in **Table 5 Attrition and Retention Rates**. This chart shows, year by year, the students leaving without graduating and those graduating each year. In the case of the institution we have used extensively through this manual as the example to illustrate the metrics, this table was not prepared because attrition and retention was not a significant element of the institutional profile, probably because the institution has the highest prestige and admissions standards in this field. However, attrition and retention take on a more complicated dimension at many institutions. To illustrate the type of data included in Table 5, we have used data from another institution (labeled Institution Y). Table 5 is also used to explain the "Brain Drain" phenomenon, which is presented in the next section.

Tables 2 to 4 presented in the previous pages summarize the retention and attrition data for this particular institution (students still at the institution or graduating from it and students leaving the institution, classified by their graduation prognosis). The graduation prognosis was determined by their GPA at the time they left the institution and students were placed in three categories: likely to have transferred to another institution and to graduate (GPA > 2.69), uncertain (GPA 2.00-2.69), and unlikely to graduate in a STEM field from another institution if they transferred (GPA < 2.00). The percentages of each group are the percentages that the subset constitutes of the whole electrical engineering group (n=25).

Of the three electrical engineering students still at the institution ("Students Still at Institution"), two had a very positive prognosis, and one had a "positive" prognosis. As mentioned above, all were presumed to be graduating in the near future.

The students leaving are classified by GPA to indicate those:

- with a likelihood of graduating somewhere else (presumed to be transferring)
- whose prognosis is unclear (because their average is acceptable but not outstanding), and
- with a poor prognosis for continued studies to a STEM degree because their GPA is low (below 2.00).

Table 4 shows that those who left, one had a GPA between 2.00 and 2.69, and the other had a poor prognosis since his/her average was below 2.00, and he/she had accumulated only 72 credits in 4.5 years. Table 4 contains cohorts representing all engineering programs. The aggregate of these programs (the total column), do not show a large number of students leaving, either in good standing or with a poor prognosis (17% total). In institutions where attrition and retention was a significant element of the institutional profile, charts indicating progress or lack of it on an annual basis were prepared showing retention rates on a cumulative annual basis in the last row, in both numbers and percentages of the cohort (see Table 5).

Data included in Table 5 could assist an institution to identify critical points in attrition for remedial action. As mentioned previously, this issue is treated in the "Brain Drain" section.

Where there is sufficient attrition to draw qualitative conclusions, the major losses come not surprisingly between the first and second year and between the second and third year. At some institutions, gatekeeper courses appear to be more problematic, at others bottleneck courses assume greater importance.

"Brain Drain"

Although not a significant element of the institutional profile for the particular institution used as an example throughout this manual, attrition and retention take on a more complicated dimension at many institutions. Besides having much higher attrition rates, the students leaving fall generally into two distinct groups:

- those leaving voluntarily (in good, even very good standing), and
- those leaving because they are not making satisfactory academic progress (either in official terms or by their own personal standards).

Those leaving in good standing appear to constitute a "Brain Drain" for the institution they left. Although these likely STEM graduates contribute to the overall LSAMP objectives, they are understandably a source of concern to the individual institutions, which make an investment in students which then do not show up in the institution's statistics. For that reason the evaluators characterize this phenomenon with the judgmental term "Brain Drain."

It describes a kind of problem which occurs when students who are apparently doing well leave the institution. Although the student may continue and complete his or her studies elsewhere, it is a subject of concern to the institution regarding recruitment, prestige, use of scarce resources, etc. There are different ways to identify and quantify the "brain drain" factor. After some experimentation, the evaluators decided on an admittedly subjective judgment of what constituted modest, good, or outstanding GPAs and minimal, modest, or substantial numbers of credits to create categories. They were then ranked as "highly probable," "likely," "possible," or "unlikely" to figure in a brain drain from the institution in question. Constructing the data base requires only that for each STEM student who leaves before graduating, the data recorders should register the major, the GPA, and the number of credits. Then they are ranked (within majors, if so desired), to see if a pattern emerges. Table 5, based on an institution and program where this type of attrition is more significant, shows how data can be displayed to help management deal with the problem.

The same divisions were used as above for determining the prognosis for graduation. Other institutions may determine that different cut-off points are more appropriate.

Table 5

Institution Y
Attrition/Retention Rates by GPA (“Brain Drain” Data)

n = 36	YR 1	YR 2	YR 3	YR 4	YR 5	YR 6	YR 7	Total	
Students leaving before Graduation GPA >2.69	1	4	1	1				7	19%
Students leaving before Graduation GPA 2 - 2.69	1	4	3		1	1		10	28%
Students leaving before Graduation GPA >2.00	2	2						4	11%
Total Attrition	4 11%	10 28%	4 11%	1 3%	1 3%	1 3%		21 58%	58%
Students Receiving Degree				1	1		7	9	25%
Retention plus Students who have Graduated	32 89%	22 61%	18 50%	17 47%	16 44%	15 42%	15 42%	15 42%	42%

Students leaving in good standing before graduation (with a GPA above 2.7) are surmised to have transferred to another institution, thus constituting a “Brain Drain” for the institution they left. The “Brain Drain” at this university may be considered modest in that only six of 36 left the institution with a GPA over 2.7. The fact that they left after an average of only two and one half years suggests some interesting possibilities. One is that they had considered, if not planned, to transfer to another institution from the beginning. They may have had a particularly unpleasant experience at the institution. There may have been personal factors unrelated to the academic characteristics of the institution that motivated the transfer. Or others. The 10 who left with only a GPA between 2.00 and 2.69 may have been salvageable, but the relatively short time that they spent at the institution before leaving tends to suggest that it may have been difficult to retain them. It is also unclear whether they became frustrated with college and dropped out or transferred to another institution. And if they transferred, did they stay in the same field?

These data suggest that an interview with the departing students may be necessary to uncover the reasons for leaving and determine what, if anything, might have been done to retain and eventually graduate these students in a STEM field. The final group had a poor prognosis, and is presented in order to clarify why we classify the first group as "Brain Drain" students, and the second group as "Unclear but possible 'Brain Drain' students." This last group did not have an auspicious start at post-secondary studies in their chosen field. These students almost certainly do not constitute a "Brain Drain" for the university. The strategy for dealing with them in order to retain and eventually graduate them in a STEM field would be substantially different than for the second group. The first group appears likely to graduate in a STEM field from another institution, and thus does not represent a loss to the minority science pool, but is a cause of some concern to the institution.

As indicated elsewhere in this manual, data sharing is needed to pinpoint what happens to them with certainty. At present, this data is only available within a university system, such as the multi-campus UPR system. In the absence of such reliable data, the evaluators provided this kind of table to support speculation on the matter. Follow-up interviews with a sample of the students would provide a clearer idea of the motivation of these presumed "brain drain" students. Data sharing would help clarify if our prognoses were optimistic, pessimistic, or accurate. It would also be informative to know how many of the credits these students had accumulated were likely to be accepted at another institution.

Step 3 - Extracting the data from the transcripts and making tabulations for identifying and profiling problem courses and their institutional impact

This step also consists of three stages and deals with data on specific courses that constitute roadblocks on the student road to graduation and related descriptive data on those courses and their impact.

Step 3 - Stage A – In this stage, courses with unsatisfactory results were listed by student. It included data on repetitions of those courses and the results of the repetitions. A, B, or C were classified as satisfactory and D, F, W, or I as unsatisfactory. In many institutions a D in a critical course--pre-requisite or required major course--was not acceptable to meet institutional requirements.

Table 6 - Worksheet: Courses with Unsatisfactory Outcomes, listed by Student, reports this data.

Table 6 Worksheet on Courses with Unsatisfactory Outcomes, listed by Student

Student #1

MATE 3171	QUIM 3002
Aug90 F	Jan91 W
Jan91 B	Aug91 C

Student #2

MATE 3172	MATE 4009
Jan91 W	Aug93 D
Aug91 D	Jan94 B
Aug92 C	

Student #4

FISI 3171	INGE 3135	INEL 3105	***INEL 4201***	INEL 4202	INEL 4205	MATE 3171
Aug91 W	Jan92 D	Jan92 F	**Jan94 W**	Jan95 D	Jan95 D	Augo90 F
Jan92 B	Aug92 B	Aug92 B	**Aug94 B**	Aug95 C	Aug95 B	Jan91 C

Student #5

INEL 4206	MATE 3031
Jan94 W	Aug91 F
Aug94 D	Jan92 C
Jan95 B	

Student #6

INEL 4201	ININ 4011	MATE 3171
Jan94 D	Aug94 W	Aug90 F
Aug94 B	Jan95 B	Jan91 C

Student #7

INEL 4201	INEL 4205	INEL 4206
Jan94 W	Jan94 W	Aug94 D
Aug94 F	Aug94 A	Jan95 B
Jan95 B		

Student #8

FISI 3171	INGE 3035	INEL 4205	ININ 4011
Aug90 W	Aug91 D	Aug93 W	Jan94 W
Jan91 C	Aug92 B	Jan94 B	Aug94 A

Table 6 Worksheet on Courses with Unsatisfactory Outcomes, listed by Student

Student #9

INEL 3105	INEL 4102	***INEL 4201***
Jan92 D	Jan93 D	**Aug93 W**
Aug92 D	Aug93 B	**Aug94 C**

Student #10

INEL 4201	INEL 4206
Jan94 D	Jan94 W
Jan95 A	Aug94 B

Student #11

INEL 3105	INEL 4103	INEL 4151	INEL 4205
Jan92 F	Jan93 W	Aug92 D	Aug92 W
Jun92 C	Aug93 B	Aug93 B	Aug93 A

Student #12

FISI 3171	INGE 3035	INEL 3105	INEL 4102
Aug91 D	Aug91 W	Jan92 F	Jan94 W
Jan92 B	Jan92 C	Aug92 B	Jan95 A

Student #13

INEL 4151	MATE 3031
Aug94 W	Aug91 F
Jan95 B	Jan92 C

Student #14

INEL 4201
Aug93 W
Aug94 D
Jan95 B

Student #15

FISI 3171	INEL 4102	INEL 4103	INEL 4202	INEL 4205	INEL 4206	MATE 3031
Aug91 D	Jan93 D	Aug93 D	Aug93 W	Aug93 W	Jan94 W	Jan91 D
Aug92 C	Aug93 B	Jan94 C	Aug95 B	Jan94 C	Aug94 D	Jan92 B
					Jan95 C	

Table 6 Worksheet on Courses with Unsatisfactory Outcomes, listed by Student

Student #16

ECON 3021	INGE 3011	INEL 3105	INEL 4151	INEL 4301	ININ 4011
Jan94 F	Jan92 D	Jan92 W	Jan93 W	Jan94 W	Jan94 D
Aug94 B	Jun92 C	Aug92 B	Aug93 C	Aug94 B	Aug94 B

Student #17

INEL 4102	INEL 4202
Jan93 W	Aug93 W
Aug93 B	Jan94 B

Student #18

INEL 4151	INEL 4202
Aug92 W	Jan93 D
Jan93 C	Jan94 B

Student #19

FISI 3171	INGE 3011	INGE 3035	INEL 4102	MATE 3172	MATE 4009
Aug91 W	Aug91 F	Jan92 F	Jan93 D	Jan92 F	Aug93 F
Jan92 C	Jan92 C	Aug92 C	Aug93 D	Aug91 C	

Student #20

INEL 4103	***INEL 4201***	INEL 4205	INEL 4301	ININ 4011
Jan93 F	**Aug93 W**	Jan94 D	Jan94 W	Aug94 W
Jan94 B	**Jan94 D**	Aug94 C	Aug94 B	Jan95 D
				Aug95 B

Student #21

INEL 4103
Jan93 W
Aug93 C

Student #22

FISI 3171	INGE 3035	INEL 4103	INEL 4151	INEL 4206	INEL 4301
Aug91 F	Aug91 D	Aug93 F	Aug94 W	Jan94 D	Jan95 D
Jan92 C	Jun91 B	Jan95 C	Jan95 B	Aug94 B	Aug95 B

Student #23

INEL 3105	INEL 4151	INEL 4205	INEL 4206	ININ 4011
Jan92 W	Jan93 D	Jan93 W	Jan94 D	Jan94 W
Aug92 C	Aug93 B	Aug94 B	Jan95 B	Jan95 B

Table 6 Worksheet on Courses with Unsatisfactory Outcomes, listed by Student

Student #24				
INEL 3105	**INEL 4102**	***INEL 4201***	**INEL 4202**	**INEL 4206**
Aug92 F	Jan94 W	**Jan94 W**	Aug94 D	Aug94 W
Jan93 B	Aug95 B	**Jan95 D**	Jan95 B	Jan95 C

Student #25	
INEL 4151	**INEL 4301**
Jan93 W	Aug94 W
Aug93 D	Jan95 B
Jan94 B	

Step 3 - Stage B – In this stage, the evaluators proceeded to identify problem courses. The individual student records of negative outcomes were scanned from Table 6.

Courses with significant numbers and/or percentages of negative outcomes relative to the size of the sample were tentatively identified as potential problem courses. For final designation as problem courses, it was necessary to identify those that fit the definition: those that cause a serious negative impact on STEM student outcomes**. In order to be classified as problem courses a significant number of students must be affected.** Courses in which only a small number of students had difficulties even though a high percentage of those taking the course had those difficulties are thus not considered problem courses for the purposes of this study.

For example, if only four students of the cohort of 25 took a particular course, it would not be considered a problem course even if three of them (75%) had difficulties. In the case used for the sample worksheets and tables, a course was considered a problem course with at least five of the 25 having difficulties in it. This procedure focuses on the genuine problem areas and gives a more manageable number of courses to deal with in compiling the full set of data on course outcomes.

Subsequently, **Table 7 - Student Results in Problem Courses (INEL4201-Electronics I),** was made for the problem courses, listing all results in those courses, one course to a table.

Table 7
Results in Problem Courses (INEL 4201-Electronics I)
COHORT STUDY 1990-91
ELECTRICAL ENGINEERING

INEL 4201– Electronics I

STUDENT I.D. #	DATE	GRADE
4	JAN 94	W
	AUG 94	B
6	JAN 94	D
	AUG 94	B
7	JAN 94	W
	AUG 94	F
	JAN 95	B
9	AUG 93	W
	AUG 94	C
10	JAN 94	D
	JAN 95	A
14	AUG 93	W
	AUG 94	D
	JAN 95	B
20	AUG 93	W
	JAN 94	D
24	JAN 94	W
	JAN 95	D
8 (TOTAL)		6/18

Note: The course was taken a total of 18 times by eight students who did not obtain a satisfactory result (A, B, or C) the first time, eight as a first attempt, eight as first repetitions, and two as second repetitions.

Upon repeating the course, six students obtained a satisfactory result (A,B, or C), and two finished with a D.

Step 3 - Stage C - As mentioned previously, in order to minimize the tedious work of a manual notation of outcomes, the transcripts are reviewed and only negative outcomes (D, F, W, I) are noted in a student-by-student record. The repetitions of any course with an initial negative outcome are also recorded at this time. Evaluators are cautioned to check with the institution before starting this process to determine if course codes or other relevant information has changed during the period the cohort was at the institution.

For the next tabulation (**Table 8 – Worksheet for Student Performance in Problem Courses – First Attempt)**, it is necessary to go back to the transcripts, which provide the raw data on all the problem courses that were identified as such in the previous step. Table 8 includes all students who took the problem courses and the result of the first attempt.

Table 8 Worksheet for Student Performance in Problem Courses (First Attempt)

	FISI	INGE	INEL									ININ	MATE	
Student	**3171**	**3035**	**3105**	**4102**	**4103**	**4151**	**4201**	**4202**	**4205**	**4206**	**4301**	**4011**	**3172**	**4009**
1	B	A	A	A	B	A	**B**	B	B	A	B	B	A	B
2	B	B	C	B	B	C	**A**	A	B	B	W	B		B
3	A	A			A	A	**B**	B	A	B	B	A		B
4	W	D	F	B	B	B	**W**	D	D		B	C	B	B
5	A	A			C	A	**B**		B	W	A	A		A
6	B	B	B	B	A	B	**D**	A	A	B	B	W		A
7	B	C	B	B	A	A	**W**	A	W	D	B	B	A	B
8	W	D	B	C	B	B	**A**	B	W		A	W	B	A
9	C	C	D	D	B	B	**W**	A	A	D	B	B		A
10	B	B	B	C		A	**D**	B	A	W	C	B		C
11	B	C	F	B	W	D	**B**	A	W	B	B	C	C	B
12	D	W	F	W	B	A							C	B
13	A	A	A	A	A	W	**B**	B	B	B	B	A		A
14	B	B	A	B	A	B	**W**	A	A	A	B	C		A
15	D	B	C	D	D	B	**B**	W	W	W	A	A	B	C
16	B	B	W	B	B	W	**A**	A	B	C	W	D		B
17	A	A	B	W	C	A	**A**	W	A	A	B	A		
18	B	B	B	B	C	W	**A**	D	A	B	B	B	A	B
19	W	F	C	D									F	F
20	B	C	B	C	F	B	**W**	A	D	B	W	W	B	B
21	A	B	B	A	W		**A**	B	B	A	B	A	A	A
22	F	D	B	B	F	W	**A**	B	A	D	D	B		B
23	B		W	C	B	D	**A**	B	W	D	B	W	C	B
24	A		F	W	B	A	**W**	D	A	W	A	A	C	C
25	A	B	B	B	A	W	**A**	B	A	B	W	B		A
	19/25	18/23	16/23	17/23	18/23	16/23	**15/23**	17/22	16/23	13/21	18/23	18/23	12/13	19/24

Counting negative results in this step duplicates part of the activity of the first review, but this partial duplication permits a check of the accuracy of the counting, since the number of first-time negative outcomes in both counting activities should be the same. With the accuracy of the account confirmed, the evaluators may feel confident in using all other data relating to negative first-time outcomes. Although one might wish to compare at the earliest possible moment to catch any errors, in practice it is easier to identify the source of any errors if the comparison is delayed until the tables are nearly complete. If the workers are careful and there is a low percentage of errors, this is an efficient strategy. Individual evaluators will have to determine the best point to make this comparison from their own experience.

Table 8 shows that for the example we are focusing on, INEL4201, 23 students of the cohort of 25 took the course and 15 obtained a satisfactory outcome on the first attempt. (The results of the eight who did not obtain a satisfactory outcomes were presented in Table 7 Results in Problem Courses (INEL4201 – Electronics I).

Although some tentative observations could be made at an earlier stage, the most pertinent observations require taking into consideration other information, such as that in Table 8.

For Electronics I (INEL4201), Table 8 reveals that these eight students who had difficulties were from the 23 students who took the course as first time takers. Since this group constituted nearly all the cohort, results in this course take on greater significance.

Step 3 - Stage D - The procedure of this stage will produce the final comprehensive table of problem courses for inclusion in the report. The previous worksheets are normally not included in the final report.

All the data resulting from the tabulations for the previous worksheets are now summed in **Table 9 – Electrical Engineering Student Performance in Problem Courses** and presented by course (i.e. INEL4201) in several categories:

- number of students in the cohort taking the course (first-time attempts)
- successful outcomes on first attempt
- unsuccessful outcomes on first attempt
- number of repetitions
- successful outcomes of repetitions, and
- unsuccessful outcomes of repetitions

A calculation of the percentages of these data is made and included which reveals the significance of the data on these problem courses more accurately than the absolute numbers.

Then, on the basis of these data, additional calculations are made as part of the more sophisticated metrics described in this manual that reveal more precisely the impact of problem courses on students and institution. These include:

- the Stymie Rate, which quantifies how often the course frustrates student progress toward a STEM degree, and

- the ICE Number, which quantifies the cost to the institution of problem courses or to students in the aggregate.

The calculations of the Stymie Rate and the ICE Number, which quantify aspects of the problem courses (gatekeeper and bottleneck), have proven interesting and illuminating in analyzing STEM programs. Simply put**, the Stymie Rate is the percentage of students unable to successfully complete a course vs. the number who attempted the course; the ICE Number is the ratio of attempts in taking the course (numerator) to successful course completions (denominator).**

Table 9 Electrical Engineering Student Performance in Problem Courses

Sample Engineering (Elect. Eng.) n = 25	Total Enrollment 1990-91 Cohort	Satisfactory Outcomes on First Attempt (A,B,C)		Unsatisfactory outcome on First Attempt (D,F,W,I)		Number of Times Unsatisfactory Class was Repeated	Successful Repeats of (D,F,W,I) Outcome (A,B,C)		Students with (D,F,W,I) Unable to Succesfully Repeat Class		Students Unable to Repeat with (A,B,C) % of Total	Index of Course Efficency (1.0 ideal)
		No	% of Total	No	% of Total		Number	% / Unsat.	Number	% / Unsat.	"Stymie Rate"	"I.C.E."
FISI 3171	25	19	76%	6	24%	3	3	50%	3	50%	12%	1.3
INGE 3035	23	18	78%	5	22%	6	5	100%	0	0%	0%	1.3
INEL 3105	23	16	70%	7	30%	8	7	100%	0	0%	0%	1.3
4102	23	17	74%	6	26%	7	6	100%	0	0%	0%	1.3
4103	23	18	78%	5	22%	6	4	80%	1	20%	4%	1.3
4151	23	16	70%	7	30%	10	7	100%	0	0%	0%	1.4
4201	**23**	**15**	**65%**	**8**	**35%**	**10**	**6**	**75%**	**2**	**25%**	**9%**	**1.6**
4202	22	17	77%	5	23%	5	4	80%	1	20%	5%	1.3
4205	23	16	70%	7	30%	10	6	86%	1	14%	4%	1.5
4208	21	13	62%	8	38%	9	8	100%	0	0%	0%	1.4
4301	23	18	78%	5	22%	5	3	60%	2	40%	9%	1.3
ININ 4011	23	18	78%	5	22%	4	3	60%	2	40%	9%	1.3
MATE 3172	13	12	92%	1	8%	1	0	0%	1	100%	8%	1.2
4009	24	19	79%	5	21%	5	5	100%	0	0%	0%	1.2
Col. 1	**Col. 2**	**Col. 3**	**Col.4**	**Col. 5**	**Col. 6**	**Col. 7**	**Col. 8**	**Col. 9**	**Col. 10**	**Col. 11**	**Col. 12**	**Col. 13**

$$\text{ICE} = \frac{\text{Col. \#2} + \text{Col. \#7}}{\text{Col. \#3} + \text{Col. \#8}} = \frac{23 + 10}{15 + 6} = \frac{33}{21} = 1.57 = 1.6$$

$$\text{Stymie Rate} = \frac{\text{Col. \#10}}{\text{Col. \#2}} = \frac{2}{23} = 0.09$$

Step 4 - Analyze the data, make observations, and draw conclusions

Explanation of the Table: Student Performance in Problem Courses

The various columns in the summary table, **Table 9 - Student Performance in Problem Courses**, represent a number of metrics that are described in detail in the following section. This table illustrates the different metrics, and it is cited as pertinent in the relevant sections.

For all categories of data of interest, it is necessary to sum the individual data to obtain a statistical profile of the cohort. See the **Sample Report in Appendix II** for a more **complete** example of what such a profile looks like. The table on the previous page (prepared as a spreadsheet) illustrates such a report.

The following section explains the nature of the data included in the tables on problem courses derived from the retrospective cohort studies, column by column, explaining what kind of information is presented and how it was arrived at.

Col. 1 (heading) **Sample Univ. X**
Engineering
(Elect. Eng.)
n = 25

This column heading presents the institution (by name or by code when the report is for broad dissemination) and a major field identifier (or the designation "Summary Table" with an additional clarifying description as appropriate: "Summary Table: Engineering"). In this case the major field is Elect[rical] Eng[ineering], and the number of records it comprised (n=25).

Col. 1 (courses)

The rest of the column presents the courses for which data was analyzed, and which were judged to provide significant cases. A key to the courses should be provided in an appendix to each report.

Col. 2 **Total**
Enrollment
1990-91
Cohort

Total first-time enrollment in the course, regardless of outcome, for the cohort whose members entered as first-time students in the 1990-91 academic year. Studies may or may not consider students who transfer into an institution.

The larger the course enrollment the greater the impact if it is a "problem" course. For example, for INEL4201 (Electronics I) 23 students of the 25 in the cohort enrolled in the course as first-time matriculators, making its overall impact high, and the degree to which it is a problem course (judged by other measures) is also high. The only students who did not take the course are likely those who left or have not yet finished their degrees.

Cols. 3 & 4 **Satisfactory Outcomes on First Attempt (A,B,C)**

No. (Col. 3)	% of Total (Col. 4)

A satisfactory outcome is defined as a grade of A, B, or C on the first attempt, given in both absolute terms (No. = Number) in column 3 and as a percentage of the total first-time enrollment in the course (% of Total**)** in column 4. For the example of INEL4201, of the 23 students who enrolled in the course as first time takers, 15 passed on the first attempt, 65% in round numbers. The evaluators consistently round percentages to whole numbers, in keeping with the scale of the sample (usually 100 cases or less).

Cols. 5 & 6 **Unsatisfactory Outcome on First Attempt (D,F,W,I)**

No. (Col. 5)	% of Total (Col. 6)

An unsatisfactory outcome is defined as D, F, W (Withdraw), or I (Incomplete) on the first attempt, both in absolute terms (No.) in column 5 and as a percentage of the total enrollment in the course (% of Total) column 6. If institutional policy and faculty/student practice combine to produce a significant percentage of students obtaining an Incomplete who subsequently complete the course in satisfactory fashion without undue prejudice to the pursuit of their STEM major, then some adjustment in the use of data on Incompletes may be warranted. In most institutions the great majority of Incompletes represent an undesirable situation, although a small minority may not. For the example of INEL4201, of the 23 who enrolled in the course as first time takers, 8 failed to pass on the first attempt, 35%.

Introduction to Cols. 7-13

Columns 7 through 13 present a variety of data for students with an "unsatisfactory outcome" on the first attempt, following up on the basic data presented in columns 5 and 6 which identify gatekeeper or bottleneck courses in more precise quantitative ways. Explanations for the specific information in each set of columns, is provided below. (Refer to Table 9 in page 26).

Col. 7 **Number of Times Unsatisfactory Class was Repeated**

The total number of attempts after the first try (repeats), by all students in the cohort taking the course, is an aggregate number that includes several components. It includes students:

- who did not repeat the course after an "unsatisfactory outcome" (none for this group)
- students who passed the course on their second try (4 repeats),
- students who passed the course with D (two repeats)
- and two students who repeated the course more than once (two repeats), whether or not they ever obtained a satisfactory outcome. In this case, both second time repeaters obtained B.

For the example of INEL4201, the eight who did not pass with A, B, or C on the first attempt repeated the course a total of 10 times.

Cols. 8 & 9 **Successful Repeats of (D, F, W, I) Outcome (A,B,C)**
Number **% of Unsat[isfactory]**

Column 8 shows the number of times the class was successfully repeated, **indicating the extent to which the negative gatekeeper or bottleneck characteristics could be overcome**. Column 9 shows these successful repeats as a percentage of the number of students who obtained an unsatisfactory outcome the first time. A high percentage indicates that although the course presents a problem, it is one that many students are able to overcome eventually. For the example of INEL4201, six of the 10 times the course was repeated there was a satisfactory outcome (A, B, or C). Those six satisfactory outcomes constitute a 75% success rate for initial unsatisfactory outcomes (6/8 = 75%).

Cols. 10 & 11 **Students with (D,F,W,I) Unable to Successfully Repeat Class**
Number **% /Unsat[isfactory]**

Columns 10 and 11 (along with columns 12 and 13, explained below) represent the other side of the positive picture presented in columns 8 and 9. Columns 10 and 11 show respectively the number and the percentage of students who, after obtaining a D, F, W, or I the first time they took the course, ***never*** obtained an A, B, or C for whatever reason. In the case of a required course, this course thus became an insuperable barrier to a continuation of their chosen academic career. These data include students who did not repeat the course as well as students who repeated the course one or more times unsuccessfully. **These figures represent how powerful the gatekeeper or a bottleneck effect was for individual students who were not successful on their first attempt**. In the case of INEL4201, two students failed to complete the course in satisfactory fashion. Of the 23 students who chose to take the course, 15 passed it with A, B, or C in the initial attempt, and six more students passed on a subsequent attempt, leaving two who never passed the course. These two constituted 25% of the eight who initially failed to pass it with A, B, or C. This index gives a measure of how difficult the course was for students who did not pass it the first time. The next two indices give a measure of how difficult it was for all students who took it and a measure of the cost of this difficulty to the institution and the students

Col. 12 **Students Unable to Repeat with (A,B,C) % of Total "Stymie Rate"**

Column 12 (also called the "Stymie Rate") shows the percentage of all students who took the course for whom the final result, whether after one or multiple attempts, was unsatisfactory. In contrast to the previous column, which indicates the difficulty for students who did not obtain a successful result the first time, this column indicates more of a level of global difficulty--for all students who took the course. **This figure gives another indication of the difficulty of the course and, perhaps more important, its place as a gatekeeper or bottleneck from a systemic or institutional perspective**. This percentage was named the "Stymie Rate," discussed below as one of the special indicators.

To calculate the Stymie Rate, ("Unable to Repeat with ABC, % of Total"), take the number of students who ***never*** passed it in satisfactory fashion (usually defined as passing with an A, B, or C) and divide by the number of those who took a particular course (counting individuals only once, no matter how many times they took the course). In the case of INEL4201, the two students (see column 10) who failed to complete the course satisfactorily constituted 9% of the 23 who took the course.

Col. 13 **Index of Course Efficiency (1.0 ideal) "I.C.E"**

The Index of Course Efficiency (ICE) calculates the "cost" to the institution to obtain each successful completion of the course. This measure, called the Index of Course Efficiency (ICE) is calculated by dividing the total times the course was taken by members of the cohort (regardless of the result) by the number of successful results (A, B, or C). It is discussed in greater detail below as one of the special indicators.

For each (high risk) course, divide the number of students taking the course (either for the first time or repeating it) by the number that complete the course with a satisfactory grade (usually A, B, or C). Each time a student takes a course counts separately. Counting both, repeaters as well as first time takers, rather than only the number of individuals who take the course, is appropriate, since each attempt represents a cost to the institution in terms of course space.

For the example of INEL4201, there were a total of 33 matriculations (23 as first-time matriculations, 10 as repeats) with 21 satisfactory outcomes (15 in the first matriculation and six as a result of repeats). The ICE Number for INEL4201 is produced by dividing the 33 total attempts by the 21eventual satisfactory outcomes to obtain the ICE Number of 1.6 for this course. In other words, students must take this course an average of 1.6 times to get a satisfactory result. Or from the institutional perspective, it takes 1.6 student inputs to obtain one successful output for the course. (We round the result to two significant digits in keeping with the scale of the sample, consistent with our practice for percentages noted in the commentary on column 4 above.)

An index of 2.0 means that the institution historically has had to give the course twice as often (either as first-time takers, repeaters, or a combination of the two) in order to eventually produce the same number of successful course graduates (those completing it with an A, B, or C) as it would if every student passed with an A, B, or C the first time. Fractional numbers--as in the example of INEL4201--are more common than whole numbers. Some students successfully complete any course on the first attempt, some repeat it one time before successfully completing it, a few repeat it several times before successfully completing it, and some never successfully complete it at all. (See the Stymie factor discussion below.)

Analyze the data, make observations, and draw conclusions

Analysis means determining what results are significant, developing hypotheses and/or explanations, and providing a meaningful description of the data. These decisions are based on experience, the style of the evaluators (for example, how speculative they wish to be), and what opportunities for follow-up research exist. In practice, the evaluators tabulated data on ***all*** courses, but included in their report only those that stood out as problematic. For our evaluators, the percentages of unsatisfactory grades that triggered identification as a problem course ranged from 25% to 40%. The threshold may well vary depending on a variety of factors in the particular environment that the evaluators are working in. For readers of the report, it may be appropriate to give an approximate range of results of the tabulations of the non-problematic courses for the reader to see how the problematic courses were selected. See the sample report included in Appendix II for an example of the kind of interpretations that are possible.

Additional Tables

From the records studied, several types of institutional (comprehensive, aggregate) data were derived, as illustrated and explained above:

(1) the graduation rate of the cohort
(2) the average study time (in years) of graduates
(3) data on students who left the STEM program in good standing
(4) data on students who graduate (or for those who have not had adequate time to finish their academic careers, are likely to graduate) in some other (usually a non-STEM) field.

In addition, a number of *additional tables* may be constructed, as the evaluators and/or administrators judge useful. A few of these that were prepared for various purposes are illustrated below.

1. Number of STEM Students Graduating by Field (Table 10)

Summary: All Science Programs
1991-92 Cohort
Number of STEM Students Graduating by Field

BS	Biology	17
BS	Chemistry	12
BS	General Science	18
BS	Liberal Studies	1
BS	Nursing	3
BS	Psychology	5
BS	Sec. Ed. Gen. Science	1
Cert.	Medical Technology	1
Total		58

Note: 13 STEM student are still matriculated and in good standing; 38.1% STEM graduation rate, and 46.7% potential STEM graduation rate

This table provides a breakdown of the fields for STEM graduates. It could profitably have been expanded to include the fields of those remaining and likely to graduate. Additional useful information could be obtained by identifying the numbers originally in each field along with those dropping out, leaving the field for another (usually non-STEM) field, graduating within the time frame specified, and likely to graduate a little later.

2. Number of non-STEM Students Graduating by Field (Table 11)

Number of non-STEM Students Graduating by Field

BBA	Accounting	1
BBA	Management	2
BBA	Marketing	1
BBA	General Bus. Adm. Studies	1
BS	Elem. Education	2
	Total	7

Note: 1 non-STEM student still matriculated; 15.2% non-STEM graduation rate, and 17.4% potential graduation rate for non-STEM students

This table shows where STEM students went when they left STEM fields but stayed at the university and continued making satisfactory academic progress. The additional information was calculated for non-STEM students in the same way as the comparable information for STEM students.

3. Comparison of Graduation Rates and Time to Graduate

Table 12 – Graduation Rates and Time Comparison of Two Cohorts, compares graduation rates and times to graduate from an earlier cohort to one impacted by the PR-LSAMP program and other institutional reform initiatives that complemented/enhanced PR-LSAMP efforts.

This table shows institutional progress through two indicators:

- graduation rates, and
- average time to graduate

Table 12 shows that time to graduate improved substantially, from 6.1 years to 5.5 years. The improvement in the graduation rate within the study period was only modest, improving from 53% to 56%, but the improvement became very large (to 76%) when the projected graduation rate was taken into account. (Sufficient time had elapsed for the first cohort to account for all or nearly all students who could have graduated.)

Looking at improvement in the indicators for the individual courses shows similar improvement in most, if not all of the problem courses (**Table 13 – Comparison of Stymie Rates and ICE Numbers)**. Stymie Rates of 13% to 30% for the 1984-86 Cohort decreased to 6 to 14% for the 1990 Cohort. Rarely the Stymie Rate went up, as was the case for Electrical Engineering 4075, which went from 16% to 23%. The ICE Numbers went down substantially in most cases, from 1.7 to 3.1 for the 1984-86 Cohort to 1.1 to 1.8 for the 1990 Cohort. Even in the case of Electrical Engineering 4075, for which the Stymie Rate went up, the ICE Number remained the same.

Table 12 – Graduation Rates and Time Comparison of Two Cohorts

Engineering Sample

	Cohort Entering from 1983 to 1986	Cohort Entering in 1990
Combined Graduation Rate (BS - STEM)	**980 (53%)**	**84 (56%)**
Combined Average Time to Graduate	**6.1 Years**	**5.5 Years**
Students in Good Standing Still at the Institution*	--	38 (25%)
Projected Graduation Rate**	**--**	**114 (76%)**
Projected Average Time to Graduate***	**--**	**5.8 Years**
Non-STEM Graduation Rate (Students Entering as STEM)	94 (5.0%)	3 (2%)
Time to Graduate as non-STEM (Initial STEM)	--	5.7 Years
Population / Sample Size	1,848	150

* About 80% of the students still in the system are expected to graduate within approximately one year.

** The projected graduation rate for the 1990 cohort is 23% higher than the average graduation rate for the cohorts from 1983 to 1986.

*** The projected average time to graduate is 0.3 years shorter than the average time to graduate for the 1983 to 1986 cohorts.

TABLE 13

Comparison of "Stymie Rates" and "ICE" Numbers for Most Difficult Courses
Cohorts Entering in 1984-86 and Cohort Entering in 1990
Sample Engineering

Course	Total Avg. Enrollment 1984-86	"Stymie Rate" 1984-86	"ICE" Number 1984-86	Total Enrollment 1990	"Stymie Rate" 1990	"ICE" Number 1990
FISI 3171	294	30%	2.9	131	6%	1.4
3172	256	23%	2.5	125	14%	1.4
INEL 4075	151	16%	2.0	53	23%	1.6
4076	87	13%	1.7	33	21%	1.7
INGE 3011	439	14%	1.6	141	7%	1.2
3016	344	13%	1.8	122	6%	1.2
3031	316	20%	2.2	63	6%	1.4
ININ 4011	189	15%	1.9	59	7%	1.4
INQU 4005	42	14%	3.1	20	0%	1.4
MATE 3031	385	17%	1.9	137	12%	1.5
3032	374	20%	2.0	131	11%	1.5
3063	333	17%	1.9	128	8%	1.4
3171	204	20%	1.8	90	9%	1.4
3172	221	19%	1.7	92	9%	1.3
4009	310	14%	1.8	120	9%	1.5
QUIM 3001	393	20%	1.7	123	5%	1.1
3002	365	24%	1.9	119	9%	1.2
4041	46	15%	2.5	23	13%	1.6
4042	39	15%	2.1	23	17%	1.8

"Stymie Rate" = % of initial enrollment unable to successfully (w/ A,B,C) complete course, i.e. students "stymied" by the course

"ICE" = Index of Course Efficiency, or the number of times course must be taken per successful (A,B,C) outcome

A Detailed Discussion of the Metrics: ICE Numbers, Stymie Rates, and Brain Drains

The PR-LSAMP Program identified the standard indicators, metrics that you are surely familiar with: graduation rates, GPAs and major averages, pass/failure rates in courses, etc. In addition, the program, with the collaboration of its external evaluators, developed some additional indicators: the Index of Course Efficiency (ICE), Stymie Rates, and Brain Drain data, which have been discussed above to some extent. This section further explains their significance.

Interpretation of the Data

(1) The I.C.E. Factor (Index of Course Efficiency)

We all know that high-risk courses cause problems for students. We also know that some of the techniques used by LSAMP programs can help students overcome these problems. This assistance, however, costs money and may also require some changes in the way the university teaches or deals with students.

To justify this cost and overcome institutional resistance, we must have strong arguments. One way to persuade the administration is to demonstrate that failure is expensive for the institution. The ICE number does this.

The ICE number, although placed at the end of the performance tables, is perhaps the most important indicator, comprehending a number of elements in student and institutional performance. ICE is an acronym for Index of Course Efficiency. It is a quantitative measure of the number of students who register for a course (new and repeat) that are required to produce one successful (A,B,C) graduate of the course.

The ICE argument to the administration is based on an analogy with manufacturing. If a manufacturer is using an old machine to make widgets, but the rejection rate for the finished product is 10%, while investing in a new machine would result in a reduction of the rejection rate to 1%, the manufacturer can easily calculate if the investment is cost effective. By multiplying the 9% avoided rejection rate by the value of a day's production and comparing it with the cost of a new machine, he can determine how many days of production it will take to recoup his investment, and therefore decide if it is worthwhile from a purely economic perspective.

Significance of High ICE Numbers

Since any failure of a student to complete a course implies a direct or indirect institutional cost, the ICE number is a good way for administrators who are cost-conscious as well as student-sensitive to see the cost in human and implied economic terms.

In practice, the PR-LSAMP program considered a course a serious problem (a genuine gatekeeper or bottleneck course) when its ICE number was 1.5 or greater. As with all of these indices, the ICE number alone tells almost nothing about the *nature* of the problem, however. It does indicate what courses to examine by other qualitative and quantitative methods to seek answers to why a course is high risk. **Its value is that it quantifies the seriousness of the problem**, presenting the information in a simple form (a single number) that an administrator can relate directly to the finances of the institution. The other information in the table, although illuminating if studied carefully, is not as easy to grasp in a single glance. Faced with the evidence provided by high ICE numbers, members of the PR-LSAMP program, professors, and administrators looked more intensively at the courses and took some remedial efforts. Some of these brought favorable results, lowering the ICE numbers of courses and promoting STEM student success.

(2) Stymie Rates

The ICE number deals with cases in which students generally pass, although not always on the first attempt. **Some courses provide an *absolute obstacle* to entering or completing a program of studies, and are not just delayed in their degree pursuit. That is, they are "stymied" in their intent to complete a STEM program of study.**

The evaluators observed that different student groups behaved in different ways with different high risk courses. Substantial variations occurred among institutions, among types of majors, and among courses regarding perseverance. These behaviors were not directly related to the ICE number. In some cases it could be seen that **a high ICE number would not necessarily mean a high Stymie Rate**. Assiduous students, although creating a high ICE number for the troublesome course, at least became successful graduates through their perseverance, resulting in a relatively low Stymie Rate.

As a general rule, **the Stymie Rate was considered problematic when 10% of the students taking the course never passed with an A, B, or C and seriously problematic when 20% never passed**. In cases where the Stymie Rate for any one course approaches the value of attrition for students in a particular major, it can fairly be concluded that the course in question (possibly in conjunction with another or others) is a major if not the major factor in attrition for the sub-cohort. The 46% Stymie Rate for Electronics at Institution Y thus represents a serious problem for these engineering students.

As with the ICE number, this indicator tells almost nothing about the cause of the problem. It does, however, indicate what courses to examine by other qualitative and quantitative methods to seek answers in that area. It also quantifies the seriousness of the problem to a significant degree. The PR-LSAMP program and its constituent partners used this indicator, along with the others, to construct and modify reforms and support programs as with the ICE number.

Uses of the Metrics

As stated in the introduction to this manual, the metrics were developed to meet a number of needs of PR-LSAMP: reporting, public relations with member institutions and their constituencies, program development (formative evaluation), and institutional decision-making. The metrics presented in this manual have assessment value in three areas--diagnostic, formative, and summative.

Diagnostic

These metrics can have a **diagnostic** function in identifying areas that need attention, whether through further study or remedial action to reduce obstacles to graduation. Indices such as the Stymie Rate and the related index in column 11 of the Student Performance table can pinpoint problem courses and even the clienteles most at risk in those courses. The ICE Number can accompany the diagnosis of problem areas in making a case to the administration or external funding agencies of the need for remedial action and the potential for a payoff of funds invested in this remedial activity. If course repetitions can be reduced, substantial funds can be saved in almost every institution, since the cost of offering the course is generally greater than the tuition income generated, without taking into account the benefit to the institution when it is perceived as a place of success rather than as a most likely place to fail. Repetitions and failures are costly to students in many ways as well, both in economic and psychological terms.

Formative Evaluation

These metrics also play an important role in **formative evaluation**, in evaluating the success of program activities on an on-going basis. Successful results on a micro level may lead to a more detailed analysis of why a certain index improved so that successful practices may be repeated and disseminated. Less successful results may lead to an analysis of the causes and elimination or modification of inefficient or ineffective activities. The brevity of this list of benefits belies the very great potential value to the institution and its students of information from formative evaluation. The success of PR-LSAMP is certainly owed at least in part to the intimate relation between formative evaluation and the crafting of the many components of its effective program. With the formative evaluation data PR-LSAMP worked with the alliance's partners to maximize the benefits of successful activities and implement new activities or modifications to constantly improve the program and the results for each segment of the institution's STEM population.

Summative Evaluation

These metrics provide impressive evidence of the success of such a program beyond the overall numbers. These metrics may play an immediate role in assisting the institution or the program in meeting its reporting requirements (**summative evaluation**), in both their comprehensive and partial aspects. In addition to dealing with overall program issues, individual components of the program environment can be extremely important. Evidence of improvement in specific aspects of student outcomes complements the improvements in the number of students matriculated in STEM fields and the number of STEM graduates. Comparative tables such as those on the Comparative Stymie Rates and Comparative ICE Numbers clearly show improvement in critical measures.