Narrowing Student Academic Performance Gaps

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Abstract- Students aspire to master key concepts in each course to earn grades corresponding to their desired levels of learning. Differences in what students should learn and what they have actually learned creates one kind of gap. Another gap, sometimes due to a lack of focus during the heat of examinations, is the difference between what students have actually learned and what they demonstrate on examinations. Together, these differences combine to form a student academic performance gap for each student. Both professors and students work together to maximize the learning process. Checks and balances are necessary to ensure that the learning process is working well and that the two kinds of gaps noted above are minimized for each student. This paper describes a five-step process somewhat like the process being required in accreditation planning to improve the learning process. Assessment data from examinations in three courses are analyzed and plans of action devised to narrow the student performance gap.

Index terms: Learning Models and Technologies, Student Performance, Feedback Principles, Accreditation Planning

INTRODUCTION

Striving to improve the next offering of a given course is the goal of every professor. As examinations are graded, each professor observes what appears to have been learned well by the students and what apparently needed more explanations. These impressions are usually formed from the student academic performance on certain questions in the examinations. As a whole, the class may have done well on some questions and not so well on others. It is these “others” that require special attention for the next class in this course. Whether consciously or unintentional, the professor vows to do a better job next time and inevitably seeks ways of avoiding those same misconceptions among future students. In accreditation terms involving a feedback process, the professor has made an assessment of the expected outcomes and must put in place a plan of action to remedy poor performances among students in this course.

This paper describes a multi-loop feedback process for improving the student academic performance based on assessments and on corrective actions. A focus is placed on the characteristics of students at various levels within the programs and on the tendencies of professors in the classroom. Actions to narrow the student academic performance gap require a combined effort on the part of the professor and the student. Each must understand and accept their participation in the partnership.

It is important to establish at the outset that this paper describes a coarse-grained structure for organizing plans of actions aimed at improving the comprehension of key concepts for all students in the class. The emphasis is not on learning theory itself (1-6) nor is it on the use of testing to determine the best ways for students having certain personality characteristics to learn optimally (7-9). Neither does it focus on the identification of factors that tend to enhance learning primarily for a subset of students such as women or minorities (10, 11). It does formulate a framework for implementing changes to enhance the academic performance of all students. As such, whatever benefits evolve from the multiple feedback strategies presented here can obviously be further improved by applying those fine-grained features for individual students and for selected subsets of students.

Following this brief introduction, the author presents a simple baseline process as a starting point and continues with a modified process keyed to assessments in previous years. Recent assessment data are presented and analyzed. Finally, corrective actions are indicated to narrow student academic performance gaps for three engineering classes in courses from sophomore to senior levels.

A SIMPLE BASELINE PROCESS

Consider a simple baseline process described in five steps shown in Table 1. These five steps tend to encompass those ingredients normally used by professors in many classes. The accompanying descriptions here for each step depict an intentionally routine “first” or baseline attempt at course organization. A modified version using these same five steps is presented next and followed later by definite actions based on recent assessments in three courses. In ABET terminology, the baseline process description might be considered as representing a first time through the process and the modified version represents a second time through. Assessment results have now been collected and analyzed leading to a plan of action to make corrections for a third pass through the process.
TABLE 1

STEPS FOR THE BASELINE AND MODIFIED PROCESSES

<table>
<thead>
<tr>
<th>Step 1:</th>
<th>Course Organization and Introduction</th>
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<td>In-Class Presentations and Exercises</td>
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<td>Step 5:</td>
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**Step 1(Basic): Course Organization and Introduction**

The professor distributes a course syllabus the first day of classes and discusses instructions and procedures for the course. Included is information on office hours, textbook, examinations, grading, course policies, accommodation for students with special needs, and a warning on cheating. The number of periods for each topic is announced. The course objectives and accreditation outcomes are often listed.

**Step 2(Basic): In-Class Presentations and Exercises**

Interactive presentations are commonplace to encourage student involvement in the introduction of new concepts. Motivation is important, especially at the beginning of new topics. For example, students appeared to have shown interest in discussing the plight of the amateur inventor who claimed to have a perpetual motion machine until the ac power calculation was shown to have omitted the power factor. Sound and sight demonstrations add to the motivation to learn about time and frequency relationships. The professor schedules review sessions both during class times and during late afternoon or early evening hours to provide additional exercises. Problems range from drill exercises to more involved design problems, depending on the level of the course and the maturity of the students.

**Step 3(Basic): Out-of-Class Assignments**

A recommended plan is for professors to have homework due every class period to promote continuity in study habits. It is important to focus on key concepts the period before the homework assignment is due. Hints can be provided to smooth over points needing clarification. Carefully list homework assignments on the daily schedule made available the first day of classes and refrain from making any changes, if at all possible. Be available during office hours always, and encourage drop-ins during the week. Encourage the use of study groups among students, but insist that they submit for grading only homework they have personally worked. Make certain that labs and projects are coordinated with the coverage of topics within the class periods.

**Step 4(Basic): Preparing for the Examination**

A good plan is to provide a list of topics for the upcoming examination one week beforehand with some indication of which topics are most important. Devote the full class period before the examination for review. Encourage questions that vary the assumptions of the problems to enlarge the scope of applications for the key concepts. Depending on whether the course is at the sophomore or senior level, indicate appropriate remarks on study habits in preparation for the examination. Ask each student to set a personal achievement goal for the examination and to consider how their preparations will help them to become ready as the time for the examination arrives. If it is a final examination, students may have more specific goals for their performance to earn enough points for a higher course grade.

**Step 5(Basic): Taking the Examination and Follow-Up**

Professors should take care to distribute the examination at the very beginning of the period, avoid unnecessary announcements that distract, and answer student questions discreetly and quietly. Students themselves should be comfortable in asking for clarifications of any confusing parts of the examination. Professors can promote learning beyond the examination period by handing each student as they leave the classroom a reduced copy of the worked-out examination on the front and back of a single sheet. This assures the student that the professor has indeed asked problems for which solutions are reasonable and that the professor has a clear idea of the time required to complete the examination. Students must then leave the vicinity and not try to reenter the classroom with questions and thereby distract the remaining students.

**A MODIFIED PROCESS**

Consider next a modified process obtained by expanding the descriptions in the baseline process. The expanded descriptions in this section do not replace the basic descriptions of the last section but instead represent additions to enhance the previous steps. As noted earlier, the modified process represents a second time through the process for narrowing the student academic performance gap. This version is based on assessments made during the past three years in courses on circuits, differential equations and linear algebra, signals and systems, controls, and probability and statistics.

**Step 1(Expanded): Course organization and introduction**

Building on Step 1 in the baseline process above, the professor also distributes a daily schedule of reading assignments, sections covered, homework assignments, team projects, and examination dates and coverage. A detailed description of grading policy is given, including how grades are assigned for different levels of accomplishment (based on total points earned). Participation in study groups is encouraged. Bonus points are announced as possible for exceptional performance on the final examination. Prerequisites and any department rules are followed, such as granting early entry into certain upper level courses only to those students who have grades of B or better in their sophomore mathematics courses, a decision made after analyzing assessment data over several semesters.
Step 2(Expanded): In-Class Presentations and Exercises

Improvements include the use of weekly recitation sessions taught by teaching assistants who have been trained the day or two before by the professor in charge. Not a new idea, the use of TAs in review sessions appears to encourage students to ask questions in a somewhat more relaxed setting. One way in which the professor can impact the student academic performance gap during this step of the process is to emphasize places in a problem solution that have caused examination difficulties among past students. For example, students make errors in the calculation of rms values by neglecting to square the time signal, perform integration correctly over intervals, divide by the period, and perform the square root operation. Being forewarned causes students to focus on avoiding mistakes in such calculations.

Step 3(Expanded): Out-of-Class Assignments

Professors are urged to create a friendly atmosphere that encourages students to come by during office hours and at other times to visit about course materials, personal concerns, career plans, or graduate school. Not only being available but giving unhurried, full attention to every student who visits is important. Schedule meetings with project teams and serve as their expert consultant several times during the semester. Become a popular reference to students who apply for graduate studies. Announce in the syllabus that office visits are encouraged and that questions about homework are allowed and that students should not be falling behind. Encourage them at this critical time; listen to their personal concerns, including any special situations hindering their progress in the course.

Step 4(Expanded): Preparing for the Examination

In addition to listing study topics one week before an examination, professors can create even more diligent study by distributing a stapled packet of four or five old examinations with worked solutions given during the past few years. The professor can help to reduce the performance gap on examinations also by seeking out students who seem to be falling behind. Encourage them at this critical time; listen to their personal concerns, including any special situations hindering their progress in the course.

Step 5(Expanded): Taking the Examination and Follow-Up

Students are encouraged to work during examinations at a pace that allows them to circle back two or three times within problems for checking procedures and calculations before proceeding to the next problem. In addition to a careful study of the solutions sheet, students are required to follow up on any concept not clearly understood. Students must be encouraged by being treated fairly not only in grading but in their eagerness to discover what they had done incorrectly on the examination and to learn the concept correctly for later use in the course or in subsequent courses.

Course1: Differential Equations and Linear Algebra

Assessments to measure student academic performance gaps made on final examinations for courses in Fall 2003 and Spring 2004 are summarized in Table 2. Corrective actions either were implemented during the academic year or else require additional planning for the next academic year.

<table>
<thead>
<tr>
<th>Course1: Differential Equations and Linear Algebra</th>
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<tbody>
<tr>
<td>Assessment data were collected in Fall 2003 on three questions for the 93 students who took the final examination in the sophomore course co-taught with a mathematics professor (12, 13) on differential equations and linear algebra. Only 35 students gave correct answers to the question on damped sinusoids, 45 answered the separation of variables question correctly, and 73 correctly answered the undetermined coefficients question. Of the 48 who answered the separation of variables incorrectly, 38 made algebra errors and 10 made errors in performing integration; all 93 appeared to understand the key concept but slightly more than half had difficulties in carrying out operations based on materials from previous differential and integral calculus courses. An analysis of these data lead to the conclusion that the poor performance on damped sinusoids would be remedied by a repeated coverage of this concept for electrical and computer engineering majors in applications in subsequent circuits courses. Student performance on the undetermined coefficients question appeared marginally acceptable; this concept will resurface during a junior signals and systems course. For the separation of variables question, a lack of preparation from calculus played a role in this study but the...</td>
</tr>
</tbody>
</table>
immaturity of students who did not follow up by identifying errors they had made in earlier examinations during the term was also important. Requiring a greater responsibility from our students seemed to be a desirable action to pursue.

To encourage greater responsibility, students are required in Spring 2004 classes to perform extra work to make up for late homework or for missed classes, according to the following course syllabi excerpt. [Within Steps 1 and 5]

All homework sets are due at the very beginning of the next period. Promptness in submitting all homework sets and in attending all class meetings are very important aspects of continuous-learning habits. A very limited number of homework sets may be submitted late, but only within two periods and with legitimate reasons. If either late homework or a missed class occurs, compensatory work is required on the same sections, such as working additional problems or outlining the section materials in detail and showing notes from lecture. Failure to do so repeatedly will result in a homework penalty which could lower the course grade.

Course 2: Circuits II

Assessment data were collected on two questions for the 21 students who took the final examination in a second course on circuits, a sophomore-level course. On a question about complex power with a lagging power factor, 18 of the students answered correctly. However, on a question about the response of linear circuits to a periodic non-sinusoidal voltage input, only 6 students appeared to grasp the key concept of superposition, despite repeated in-class examples and assigned homework. This was very disappointing.

The associated corrective action [within Steps 2, 3, and 4] has a two-fold approach:

First, the superposition concept, studied in Circuits I, was discussed again at the beginning of Circuits II in Spring 2004. This concept was emphasized in variable frequency discussions and received stronger emphasis on Fourier series analysis late in the semester. Second, a question on this concept was placed on the final examination. Repetition is the key to the corrective action.

Finally, it can be noted that 11 of the 22 students in the signals and systems course in Spring 2004 came from the Circuits II class of Fall 2003. Performances on the final examination for the signals and systems course in Spring 2004 showed that the extra emphasis on frequency response appeared to have resolved the deficiency identified earlier.

Course 3: Control Systems

Assessment data were collected on two questions for the 27 students who took the final examination in the senior controls class. On the root locus question, 22 students gave correct solutions, while poorer performances were noted on the three parts of the question on the use of frequency response (Bode) methods for the analysis and design of feedback controllers. In particular, 22 responded correctly on phase margin, 18 on gain margin, and 15 on stability analysis. In summary for the frequency response question, 55 correct responses and 29 incorrect responses were obtained. These were students who had worked in multidisciplinary teams using both root locus and frequency response analysis in their team reports.

Corrective action [within Steps 2, 3, and 5] is to rethink the traditional controls algorithm emphasis being used both for continuous and digital control systems.

In particular, this analysis technique driven course will be changed to include the many possibilities using Matlab not just as a project tool but as a means of identifying early in the course parameter changes on time and frequency responses. Removing some of the harsher mathematical algorithms and replacing them with simulations appears to be a positive approach in view of this new assessment data. These extensive changes will require additional efforts to implement when the course is offered next in Spring 2005.

In each of these courses, specific recommendations based on feedback principles applied to the learning process were made to narrow the student academic performance gap. The emphasis of this paper is not simply that students failed to demonstrate learning of a particular concept on a final examination, but rather presentation of a definite plan of action that can be followed in advance by the professor and the student working together to avoid misconceptions and narrow the performance gap. The contribution of this paper is not the reporting of assessment data and corrective actions for these particular courses but the development of an assessment and corrective action process to implement specific improvements. The data show that the process appears to be a feasible approach and has been successful for students in these courses.

Discussion

An analysis of assessment data to form corrective actions in a feedback process for narrowing student performance gaps is obviously similar to the EC 2000 process. The process is iterative; corrective actions applied now produce results for assessment during the current year. Deciding on which data and how much data to collect is important (14) and deciding on plans of action is often not obvious.

One might question the premise of why it seems to be important to narrow student academic performance gaps. This goal is not listed as a direct outcome for EC 2000, but it does have a highly positive influence on the professional and personal lives of students. If students perform well on their examinations in a strong engineering program, they will likely satisfy EC 2000 outcomes and, more importantly, build their self-esteem and reach for higher goals.

Not addressed previously in this paper was an issue posed earlier about two kinds of gaps. One gap was based on a lack of knowledge and the other on a lack of test-taking skills. It appears that poor performances cited in the assessment data may have been due to a lack of knowledge. On the other hand, the anxiety gap due to forgetfulness or a lack of testing skills was not identified directly in the assessment data. It may well be beyond the scope of this study to attempt to...
distinguish between these two gaps and just acknowledging them may suffice for the purposes here. The suggestion for students to check and recheck their solutions during testing is a recommendation which may reduce the anxiety gap (15).

Table 3 shows the results of a survey of Circuit II students in Spring 2004 regarding their views on why points were deducted for their performances on Exam 3 during the latter part of the semester. Students reported in over 62% of their responses that points had been deducted because of errors due to their anxiety, calculation errors, or stress during the examination. If these data are representative, then an emphasis on the examination preparation with regard such issues as the phrasing of questions to avoid confusion, may well become a predominant concern.

Finally, the assessment data from final examinations provide useful information on how well the course satisfies the needs of the program with the department. As such, it may be worthwhile to make this information available to the other professors who regularly teach this course. Moreover, the data may also be useful for EC 2000 assessment; it may indicate a wide-spread problem present as well in other courses in the curriculum.

**TABLE 3**

**STUDENT VIEWS ON WHY POINTS WERE DEDUCTED**

[Multiple Responses Per Student]

<table>
<thead>
<tr>
<th>Reason</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Due to Lack of Knowledge of Background Concepts from Earlier Courses:</td>
<td>5 responses</td>
</tr>
<tr>
<td>Due to Lack of Understanding of Technical Concepts from this Course:</td>
<td>12 responses</td>
</tr>
<tr>
<td>Due to Anxiety, Calculation Errors, or Stress during the Examination:</td>
<td>47 responses</td>
</tr>
<tr>
<td>Due to other Reasons:</td>
<td>11 responses</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Multiple feedback strategies based on forming corrective actions due to the analysis of assessment data have been used to further refine an improved process for narrowing student academic performance gaps. Examples featuring three classes taught in Fall 2003 showed that assessment data revealed specific actions which were implemented in Spring 2004. Further corrective actions will be implemented during the coming academic year.

**REFERENCES**


