Undergraduate and Graduate Education Activities of Current Engineering Research Centers

2006 Report of the
ERC Education Assessment and
Dissemination Task Group

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Summary

In November 2004, the Engineering Research Centers (ERC) Program in the Division of Engineering Education and Centers (EEC) of NSF formed an ERC Education Assessment/Dissemination Task Group. The Task Group was charged with advising and assisting the ERC Program in documenting and categorizing education innovations produced by the centers and in investigating, assessing, and calibrating the relative educational achievements of research fields represented by clusters of centers organized by technology focus. Members of the Task Group comprised representatives of the ERCs, with Win Aung of EEC serving as coordinator.

Working closely with the Division Director of EEC and the Leader of the ERC Program from November 2004 to June 2006, the Task Group carried out a study, the initial phase of which has been aimed at documenting the accomplishments and productivity of the ERCs in their education activities at the undergraduate and graduate levels. In addition, the study seeks to document and calibrate the relative education achievements in the research fields represented by technology clusters of centers.

The scope of the study is confined to the twenty-two centers supported in Fiscal-Year 2005 by the ERC Program. Data for the study are derived from the education reports submitted by the centers in Fall 2005 and Spring 2006. These reports deal with undergraduate and graduate education activities undertaken by the centers since their inception, covering center output in periods that range from two to ten years. Specific education activities include: new and modified courses; new major and minor emphases; new certificate programs; and new degree programs.

The present report underscores the high output by the centers in the production of new and modified courses derived from research carried out by the centers. For new and modified courses, the present study presents quantitative information on the degree of success of the centers in producing new and modified courses (that is, pre-existing courses updated by incorporating results from the ERCs' research).

It was found that the centers are highly successful in introducing into the courses a system focus and multidisciplinary content, two of the key ERC education attributes. More than 60% of the courses developed under NSF support possess these two attributes. Secondary attributes are: team-teaching of courses; teaching by multidisciplinary faculty; external review; and adoption by more than one institution, and in these attributes the center outputs are 35%, 33%, 25%, and 19%, respectively.

The productivity of the four ERC clusters is also examined to provide an insight into their absolute and relative productivity. The Microelectronics and Information Technology (Micro/IT) Cluster, comprising 36% of the center population, is found to have produced 60% of the new courses, with the remaining three clusters trailing at between less than 10% to about 15%. For modified courses, the Micro/IT cluster also leads with 35% in overall course production, but the Bioengineering Cluster is also an important producer of courses in this category. Results comparing the output of each cluster with that of the rest of the center population are given in the report.

In addition to an Activity Index, we have employed per center data to probe cluster productivity. The results show variability across clusters as well as between new and modified courses. Whether the variability is random or caused by deliberate planning on the part of the centers is currently unknown. For example, some centers in a given technological cluster may choose to focus on developing modified courses instead of new courses, or *vice versa*. The activity index could be also used to examine the relative productivity of individual centers. These topics are outside of the scope of the current phase of this study but deserve to be investigated.

A comparison of the performance of single-institution centers (SICs) and multiple-institution centers (MICs) shows that MICs clearly outperform the SICs in the production of new and modified courses that possess the ERC education attributes.

Finally, the effects of the age of a cluster on its productivity are examined, leading to the conclusion that age has only a minimal impact on the centers' ability to produce courses that have the ERC education attributes. Centers could very well decide to start a few courses, and then continue to work on them to improve them, instead of starting work on other courses. Though outside the scope of the present study, here too it would be instructive to study how true this conclusion applies across the centers within any specific cluster.

TABLE OF CONTENTS

1. Introduction

In this report, we discuss the results of an investigation concerning the education activities of the Engineering Research Centers (ERC) Program, comprising 19 Engineering Research Centers and 3 Earthquake Engineering Research Centers (EERC), hereafter called ERCs. The report details the results of an ERC Education Assessment Study the principal objective of which is to document the accomplishments and productivity of the ERCs in their education activities at the undergraduate and graduate levels. Another purpose of the study is to categorize the extent of the education innovations produced by the ERCs with a view toward providing an assessment and calibration of the relative education achievements of research fields represented by technological clusters of centers.

In November 2004, the Engineering Research Centers (ERC) Program in the Division of Engineering Education and Centers (EEC) of NSF formed an ERC Education Assessment/Dissemination (EAD) Task Group. The Task Group was charged with advising and assisting the ERC Program in documenting and categorizing education innovations produced by the centers and in investigating, assessing and calibrating the relative education achievements of research fields represented by clusters of centers. The Task Group was not charged to evaluate the accomplishments of individual centers.) Members of the Task Group comprised representatives of the ERCs, with Win Aung of EEC serving as coordinator. The official Charge to the Task Group is attached to this report in Appendix 1.

Working closely with the Division Director of EEC and the Leader of the ERC Program from November 2004 to June 2006, the Task Group carried out a study the first phase of which has been aimed at documenting the accomplishments and productivity of the ERCs in their education activities at the undergraduate and graduate levels. In addition, the study seeks to document and calibrate the relative education achievements of research fields represented by technology clusters of centers.

The scope of the study is confined to the twenty-two centers supported in Fiscal Year 2005 by the ERC Program. Focused on the education activities at the undergraduate and graduate levels, the study analyzes the quantitative activity output achieved by clusters of centers, but does not deal with quality. Furthermore, it is not the intent of the present study to investigate the productivity of individual centers.

The four (4) general criteria employed in the study are the following:

a. The degree to which education innovations in the ERCs attain the desired education attributes relative to the ERC Program goals as described in public documents including Program Solicitation, Annual Report Guidelines, and Performance Review Criteria; see Sec. 4 in the following.
b. The relative productivity of the ERC technological clusters.
c. The influence of the number of collaborating institutions in the center.
d. The influence of the duration of funding.

The EAD Task Group members mainly communicated by e-mails, and had two face-to-face meetings, during the ERC Annual Meetings held in November 2004 and November 2005. At the ERC Annual Meeting in November 2004, the Task Group convened a workshop to solicit feedback from interested persons from the ERCs. The feedback received during the workshop and later by e-mails was used to guide the progress of the work of the Task Group.

Based on this feedback, and in coordination with the Task Group, the ERC Program developed an Education Assessment Questionnaire, which was mailed to the management of all centers in June 2005. Each ERC was requested to submit an Education Report, due in August 2005. Seventeen (17) of the 22 centers responded to this initial call for education reports, while the remaining 5 responded following a second call sent out in March 2006. Data from the 22 education reports formed the basis of the study, which culminated in present report.

2. Contents of the Education Assessment Questionnaire

The ERC undergraduate and graduate education innovation process is based on a system of synergistic education components that emanate from ERC research. There are five components in the ERC Program education activities:

a. New courses developed by the centers and inserted into the curriculum
b. Modified pre-existing courses (that is, pre-existing courses updated by incorporating results from the ERC)
c. Major and minor disciplinary concentrations or emphases
d. Certificate programs incorporated into the syllabus
e. New degree programs

The Education Assessment Questionnaire, sent to the ERCs as a part of the Assessment Study on June 10, 2005, was designed to allow the centers to summarize their accomplishments in undergraduate and graduate education relative to the general criteria discussed in Sec. 1. Specifically, the Questionnaire requested the following information:

a. Emphases of education activities.
b. A detailed description of education activities including: new courses; courses modified; full degrees derived from ERC research; new degree majors or minors programs; and new certificate programs. For example, for each new or modified course, the questionnaire requests information relating to the following twelve items:

<u>Course No. 1</u>

1. Title:
2. Level of the course:
   ____Undergraduate ____Graduate ____Both
3. Educational objectives. (Please use as much room as necessary):
4. Major topics in course syllabus:
5. Is system focus incorporated in the course? (Please check one)
   ___NO___YES. If “YES”, please describe below the system aspects of the course:

6. Describe how ERC research has impacted the development of the course.
7. If this is a multidisciplinary course, please list the disciplines involved.
8. If this course is team-taught, please list the disciplines represented by the faculty.
9. Has the course been a part of the portfolio reviewed by one or more external accreditation bodies such as ABET? (Please check one)
   ___NO___YES. If "YES" Please Indicate Below the Name(s) of the Accreditation Body(ies):
10. General description of the course.
11. Related publications, including links to websites.
12. List the institutions that are using this course.

3. Education Reports Received

The 22 ERCs, whose education reports are the basis for the present study, are identified and listed in Appendix 2. The 22 centers may be categorized as follows:

a. In the ERC Program, the centers are grouped under four clusters, each representing a broad technology area. The four clusters are:
   i. Bioengineering (Bioeng.), with 6 centers, comprising 27% of the center population;
   ii. Manufacturing and Processing (Manuf/Proc), with 5 centers (23%);
   iii. Earthquake Engineering (Earthquake), with 3 centers (4%); and
   iv. Microelectronic Systems and Information Technology (Micro/IT), with 8 centers (36%).
b. Seven (7) centers (32%) are single-institution centers.
c. Fifteen (15) centers (68%) are multi-institution centers; that is, centers with more than one core partner institution.
d. Five (5) centers (23%) are within 2-5 years (2-5YC) of inception, and they are classified in the present study as "new centers."
e. Centers in their 6-10 years of funding (6-10YC) are classified in this study as "old centers." There are seventeen (17) such centers (77%).

4. The Six Education Attributes of the ERC Program

We structured the questionnaire to give visibility to the accomplishments and education innovations of the ERCs in the context of the education attributes of the ERC Program. At the same time, the questionnaire also provides a quantitative basis for assessing the productivity of the centers in terms of these education attributes. For new and modified courses, the six education attributes, as described in guidelines for annual report guidelines and program review criteria [see Ref. 1-3], are:

a. A strong system focus.
b. High multidisciplinary course contents.
c. Highly multidisciplinary faculty.
d. Strong involvement of team teaching.
e. Strong emphasis on external review.
f. Many institutions are adopting the courses.

A system focus is central to an ERC. This is stated, for example, on p. 5 of [1] and p. 5 of [2], and reflected in the "Systems Vision & Value Added" criteria in [3]. Cross- or multi-disciplinary faculty or course compositions as desirable ERC attributes are implicit in the system focus and the collaborative, diverse, and multiple-institution composition of each ERC, but are also explicitly stated in [2] on p. 3 as well as under several review criteria in [3].

The degree to which an ERC uses faculty teams in teaching provides a measure of the level of efforts employed by an ERC to implement "cross-disciplinary, cross-institutional culture" as required under several review criteria [3]. The "external review" attribute follows from the criterion in [3] that requires an ERC to include outside input on planning, project review, and assessment; see p. 5 in [3].

Dissemination of educational materials is an important function of an ERC; see, for example, p. 22 of [1], p. 33 of [2] and p. 5 of [3]. Furthermore, 15 of the ERCs carry out their work involving multiple universities. Course adoption by multiple institutions as an attribute provides a measure on the degree of success that an ERC has in its dissemination efforts, and in integrating its course development and implementation activities across its partner institutions and beyond.

In the present study, the quantitative information furnished by the centers is interpreted in order to provide data with respect to the four general criteria listed in Sec. 1. The results are discussed in the following sections.

5. Basic Results

Results of the present ERC Education Assessment Study are presented in the following sub-sections.

a. Productivity since Inception of Current ERCs

The productivity since inception of the twenty-two (22) centers is represented by a total of three hundred and eight (308) activities. These have been categorized under the five (5) components indicated in Sec. 2, and are presented graphically in Figure 1(a).

The high productivity of the centers in development of new and modified courses, and relative low level of productivity in the remaining education activities, is evident. The exact numerical distribution among the five components for the 22 ERC respondents, denoted from a – v in Appendix 2, is as follows:

(i)	No. of New Courses (no. of centers involved):	143 (20)
(ii)	No. Modified Courses (no. of centers involved):	138 (15)
(iii)	Major/Minor Emphases (no. of centers involved):	13 (7)
(iv)	Certificate Programs (no. of centers involved):	10 (8)
(v)	New Degree Programs (no. of centers):	4 (4)

TOTAL ACTIVITIES (NO. OF CENTERS): 308 (22)

For each component, the number of activities is given with the number of centers involved provided in parenthesis. Thus, 20 centers have developed the 143 new courses, and 15 centers have produced the 138 modified courses. Other major education initiatives spawned by the ERCs include 4 new degree programs, 10 certificate programs, and 13 major and minor focus areas.

The overall performance of each of the 4 ERC clusters is shown in Figure 1(b). The Micro/IT cluster is clearly a standout in total production of new courses, in part because there is the highest number of centers in this cluster. There is a more even distribution among the clusters in producing modified courses, with three of the four clusters each in the 35 – 50 range.

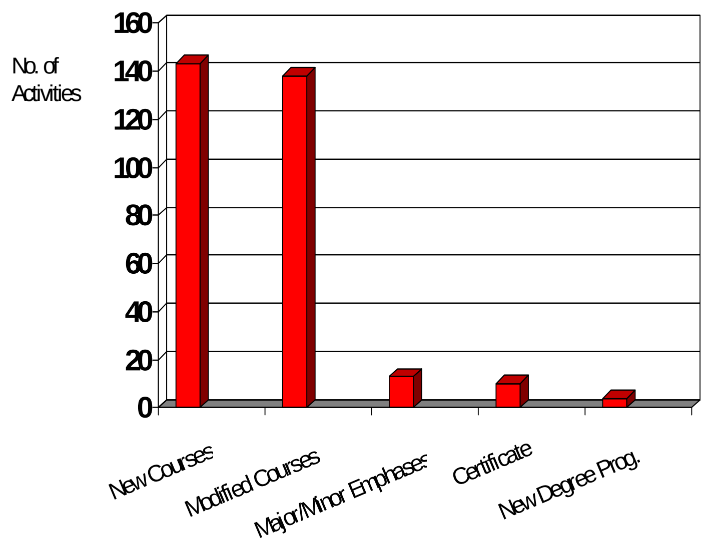

Figure 1(a)
Education Activities since Inception of Current ERCs

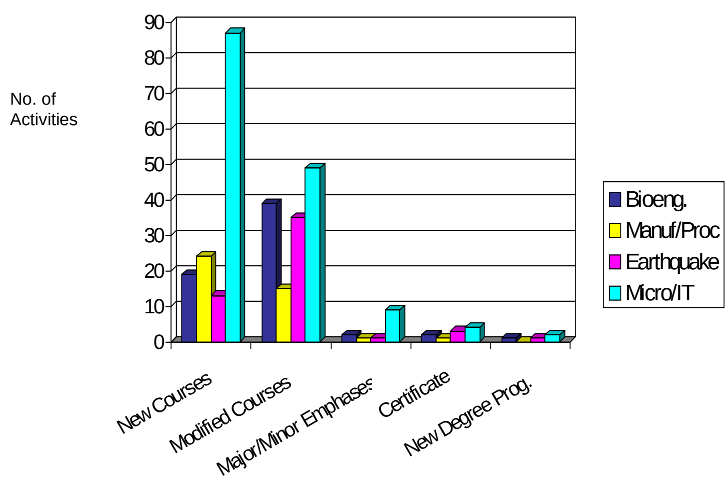

Figure 1(b)
Education Activities of the ERC Clusters

To gain additional insight into the productivity of the clusters and how they divide their focus between new and modified courses, the corresponding data shown in Fig. 1(b) are re-cast in terms of per-center averages for the clusters. Denoted as “Cluster Averages,” the results are shown in Appendix 3.

For total course production that combines new and modified courses, the Micro/IT Cluster is the most productive, averaging 17 courses per center. The Manuf/Proc Cluster ranks last with 7.8 courses per center.

A different perspective and further differentiation among the clusters emerges when new and modified courses are viewed separately. In new courses, the Micro/IT Cluster remains the top-ranked cluster with a 10.88 cluster average; however, in modified courses, their ranking drops to 3rd among the four clusters, with a 6.13 cluster average. The Manuf/Proc Cluster, ranking last overall as discussed above, ranks 2nd for new courses with an cluster average of 4.8, far below Micro/IT, the top-ranked cluster with a cluster average more than twice as high at 10.88. In modified courses, Manuf/Proc ranks last, producing an average of 3.0 courses per center.

The lowest average for new courses is given by the Bioeng. Cluster, with an average of 3.17 courses per center.

Of interest is the Earthquake Cluster. In new courses, this cluster trails all others with a 4.33 courses per center average, but in modified courses, it beats out all the rest with an 11.67 cluster average.

b. Productivity in New and Modified Courses

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Figures 1(a) and 1(b) show that the most significant impact of the ERCs is in their production of new and modified courses. New and modified courses are arguably the most effective way for centers to disseminate and propagate their vision and mission. These courses may be offered year after year and, through them, impact the largest number of students among the core partner institutions. Of course, courses are also available for adoption and adaptation by institutions outside the ERC.

In the remainder of this report, we focus on New Courses and Modified Courses. For courses, answers to Questions 5, 7, 8, and 9 provide insight into one of the main issues for the Assessment Study, viz., the degree to which education innovations possess the desired education attributes as described in NSF guidelines for strategic planning and renewal review [1, 2].

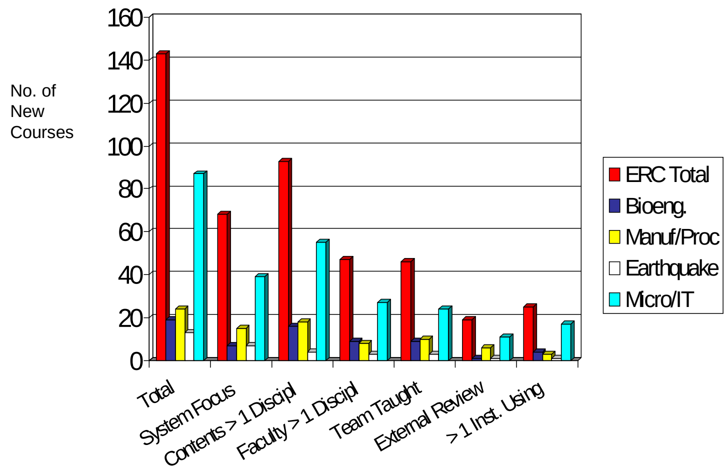

Figure 2(a)
ERC Program Summary for New Courses

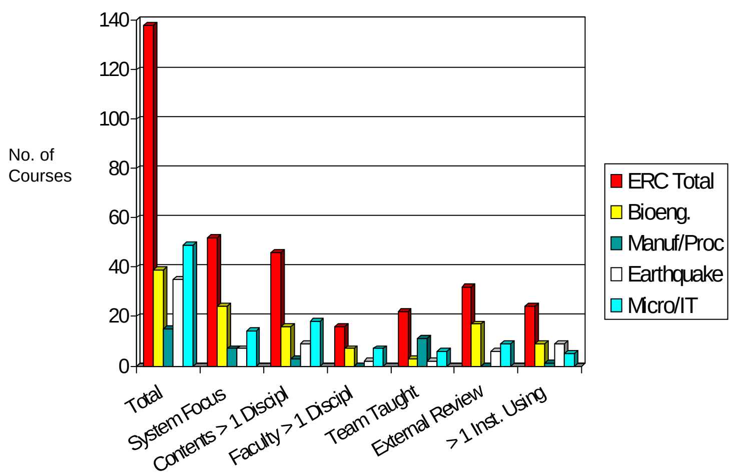

Figure 2(b)
ERC Program Summary for Modified Courses

In the present study, progress toward achieving the ERC attributes (see Sec. 4) has been characterized quantitatively using the following measures:

a. No. of courses with a system focus
b. No. of courses with multidisciplinary contents
c. No. of courses with faculty from multiple disciplines
d. No. of courses that are team-taught
e. No. of courses that have been subjected to external review
f. No. of courses being used in more than one institution

For new and modified courses, the results are plotted in Fig. 2(a) and Fig. 2(b), respectively.

Shown in Fig. 2(a) is the combined total output by the ERCs as a whole as well as the contributions by the individual clusters. The total center productivity of new courses, as indicated by data for "ERC/EERC Total" in Fig. 2(a), may be summarized as follow: (i) about 70 out of 143, or about 50%, have a system focus; (ii) about 90 or 60% have multidisciplinary contents; (iii) about 50 or 35% are taught by a multidisciplinary faculty; (iv) also about 50 or 35% are taught by multiple instructors (i.e., a teaching team); (v) about 20 or 14% have been reviewed by an external body such as ABET; and (vi) about 18 or 14% have been adopted by more than one institution. The relatively high productivity of the Micro/IT Cluster may be noted.

For modified courses, the corresponding numbers are plotted in Fig. 2(b), and they are, respectively, (i) about 50 or 36% is system-focused; (ii) about 45 or 33% have multidisciplinary contents; (iii) about 15 or 11% taught by multidisciplinary faculty; (iv) about 20 or 14% are taught by more than one instructor; (v) about 30 or 22% have been subjected to external review; and (vi) more than 20 or 14% have been used in more than one institution.

For modified courses, the Micro/IT Cluster is a standout in 5 of 6 categories. As will be shown later in Sec. 5.8, this should be viewed in light of its population share.

c. Comparative Study of Education Activities of ERC Clusters

Centers in the ERC Program are clustered under four broad technological areas. It is the intent in the present study to provide an analysis of the education activities in these clusters so as to provide a comparison of the output of these clusters. Such a comparison will be helpful in categorizing the extent of the education innovations produced by the ERCs with a view toward assessing and calibrating the relative education achievements of centers classified by major research fields.

Since the number of centers in each cluster varies significantly, we will refer to what we call the cluster's "population share" which is defined as the ratio of the number of centers within a cluster to the total number of centers, which is 22.

Within the limit imposed by a relatively small sample size of 22 total centers, a knowledge of the relative performance of clusters is nevertheless helpful in eventually uncovering the reason why some clusters are more productive than others. This can lead to steps being taken to help centers become more productive.

To this end, the present study focuses on the absolute accomplishments or productivity of the clusters in each category. Also of concern is productivity as a percentage of the respective total productivity for all centers in the respective education activity.

For new and modified courses, the results for each of the four clusters are compared against those for the rest of the center population. The results are presented in Sec. 5.4 – 5.8. The data for all clusters are summarized in Sec. 5.9 using the Activity Index.

In Sec. 6 we discuss the effect of the number of core partners in a center. We conclude by looking into the influence of funding duration in Sec. 7.

d. Comparison of the Activities of all Centers

The relative accomplishments of the center clusters in attaining the six education attributes for new and modified courses are shown in Fig. 3(a) and Fig. 3(b), respectively.

Measured against the overall output of all centers for new courses, Fig. 3(a) and Fig. 3(b) indicate that:

a. For new courses, the most highly accomplished cluster is the Micro/IT cluster, which produces 60% of the total number of new courses, with the remaining three clusters trailing at between less than 10% to about 15%.
b. The Micro/IT cluster has the largest percentage, at over 55% of the ERC total, of new courses with a system focus, while other clusters have productivity ranging from 10% to a little over 20%. The Micro/IT cluster plays a similar dominant role in each of the other five attributes in which the productivity of the Micro/IT cluster ranges from over 50% to almost 70%. The productivity of the Micro/IT cluster in both new and modified courses is particularly striking since the centers in this cluster comprise, as noted in Sec. 3, only 36% of the total.
c. For modified courses, the Micro/IT cluster still leads with over 35% in overall course production, but the Bioeng cluster is an important producer in this category. It especially shines in the ERC program education attributes by assuming the lead with over 35% of courses with System Focus, and over 50% in External Review. Bioeng. is tied for the lead in multidisciplinary faculty and in adoption at more than one institution, is a close second in multidisciplinary course contents but is at 3rd place at about 15% for team teaching.

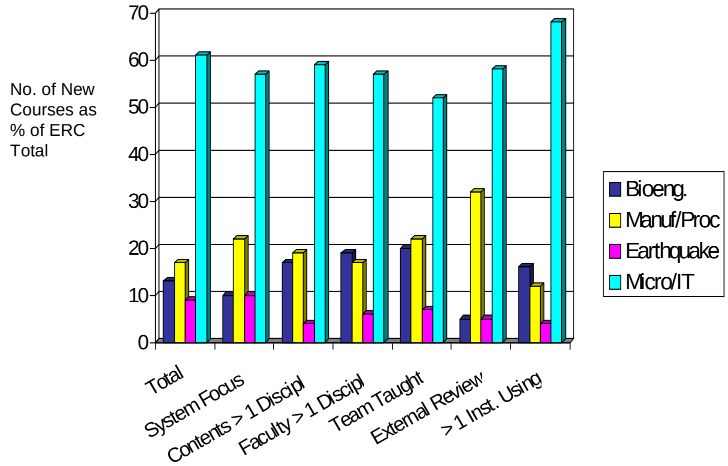

Figure 3(a)
Program Summary for New Courses as Percentages of ERC Total

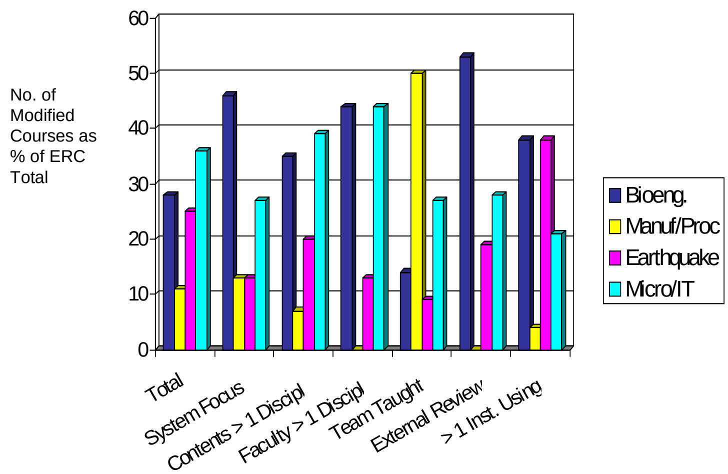

Figure 3(b)
Program Summary for Modified Courses as Percentages of ERC Total

The factors that lead to the dominance of Micro/IT over other clusters in new courses, and the appreciably higher productivity of Micro/IT in new courses than on modified courses, have not been investigated. Centers comprising the Micro/IT Cluster deal with microelectronic and information technology research, in areas such as neuromorphic engineering, nonlinear optics, electronic and bio-electronic systems, sensing of the atmosphere, wireless systems, subsurface sensing and imaging, integrated media systems, and power electronics. Clearly, to these centers, it has been either more convenient or necessary, or both, to develop brand new courses than updating what already exists. It could be that new topics emerging from ERC research fall completely outside the syllabuses for pre-existing courses, so that new courses must be developed for these topics.

e. Comparative Study of Bioengineering and Non-Bioengineering ERCs

The VaNTH ERC is the only center in the ERC Program that deals exclusively with education research. The center is a part of the Bioeng. Cluster. It is useful to examine the productivity of this cluster and the impact of VaNTH, in relation to the rest of the ERC Program. The resulting information could be used in future decisions concerning the efficacy of establishing education-focused centers in other disciplines.

Figures 4 and 5 highlight the Bioeng. contributions to the production of new and modified courses in the ERC Program. In each figure, the information is presented in absolute numbers as well as percentages for Bioeng. and non-bioengineering (Non-Bioeng.) centers. In looking at the information presented, it is useful to keep in mind that Bioeng. centers constitute 27% of the total ERC population, as noted in Sec. 3 and indicated by the vertical bar and the red line in Fig. 4(b).

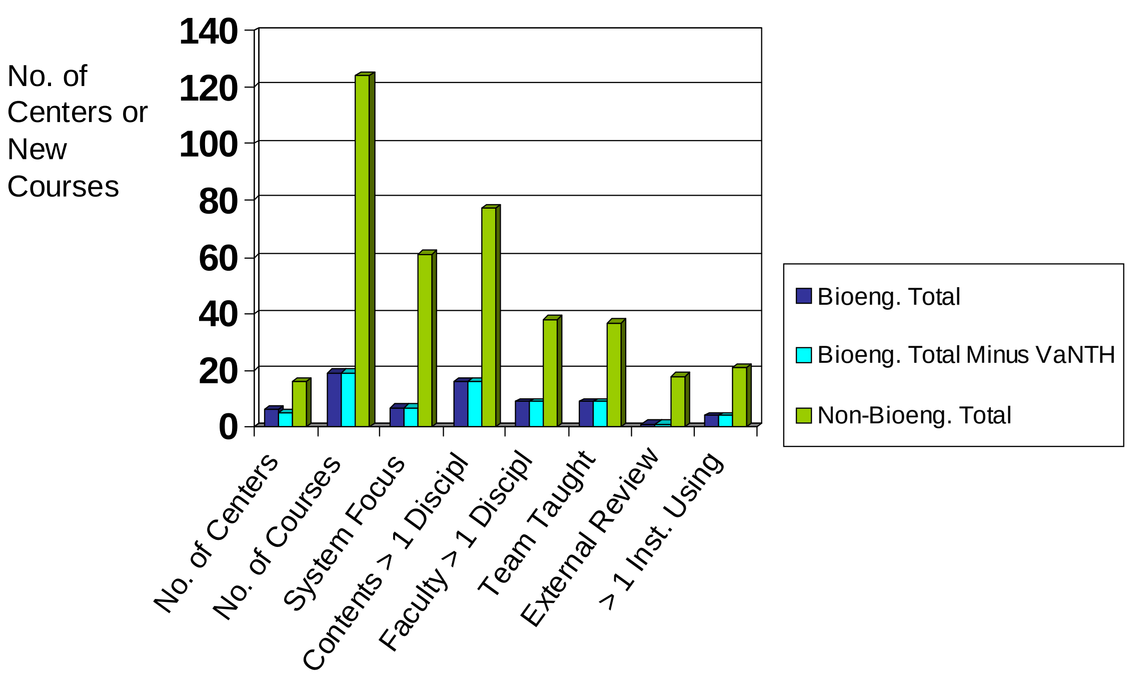

Figure 4 (a)
New Courses: Bioengineering vs Non-Bioengineering Centers

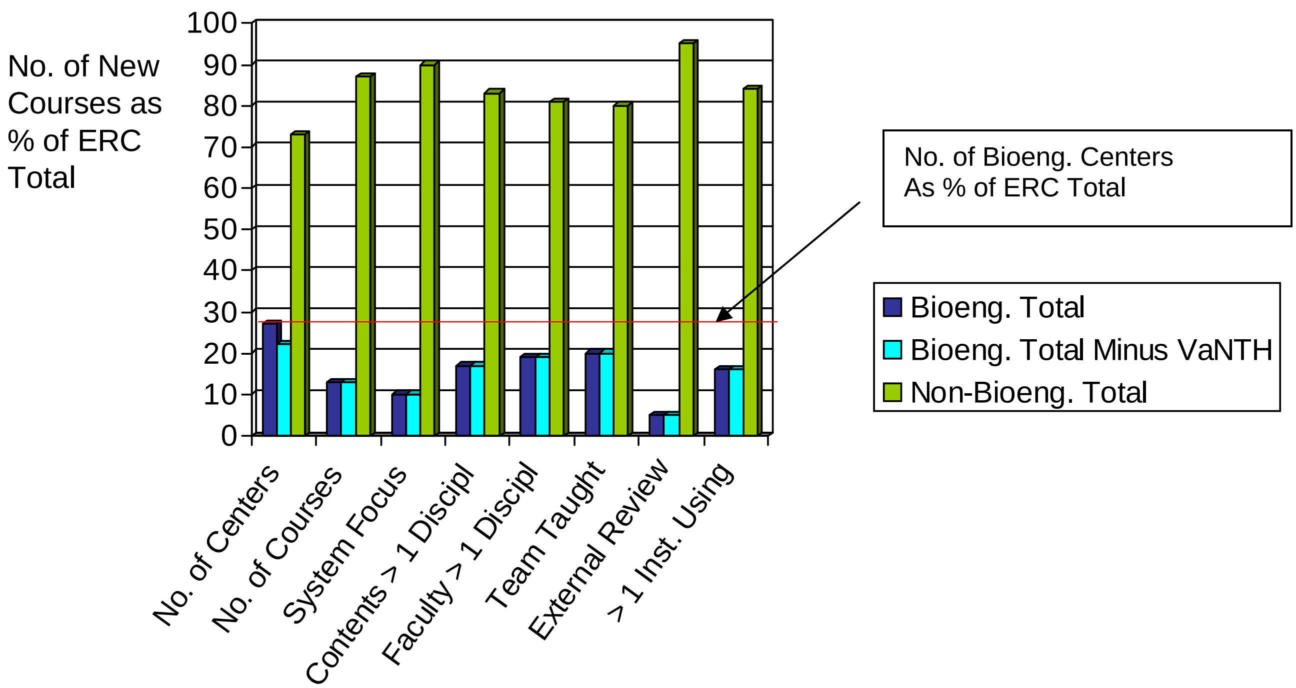

Figure 4 (b)
New Courses: Bioengineering vs. Non-Bioengineering
Centers as Percent of ERC Total

Based on the information presented, the following observations may be made:

a. Figure 4(a) shows that the total productivity of new courses by the Bioeng. Cluster is relatively small as compared with that by non-Bioeng cluster. Furthermore, the contribution by VaNTH is relatively insignificant in new courses.
b. Bioeng. centers produce just over 10% of ERC new courses; see Fig. 4(b). Their productivity of new courses with ERC education attributes is also below their 27% share of the center population, being in the 5% - 20% range.
c. It may be seen from Fig. 5(a) that Bioeng. centers produce close to 40 modified courses, or close to 30% of the ERC total, roughly commensurate with the 27% share (Fig. 5(b)) of Bioeng. center population. It is clear from Fig. 4(b) and Fig. 5(b) that, on a percent basis, Bioeng. centers have been more successful in injecting ERC education attributes into modified courses than into new courses. Thus, in five of the

six education attributes, Bioeng. center productivities are in the 35% - 55% range, the exception being in team teaching, where the productivity is about 15%. Here, the impact of VaNTH is much more significant. Figure 5(b) indicates that with VaNTH included, the productivity of the Bioeng. Cluster in System Focus is 45% and this falls to just over 10% when VaNTH is excluded. Similarly, the productivity drops to less than 15% from over 35% for adoption at more than 1 institution when VaNTH is excluded.

In summary, VaNTH has been shown to be a major contributor to the portfolio of education activities in the Bioeng. Cluster, particularly in modified courses. Its relatively smaller impact in new courses may be the result of a conscious decision made by faculty to start just a few new courses and continue to upgrade and improve them, instead of starting a lot of new courses. It may also characteristic of a center in a particular new discipline that is highly multidisciplinary, making it advantageous for the center to emphasize adaptation of pre-existing courses, instead of starting a lot of new courses all of a sudden. This may not apply in all new disciplines, as the variability in the results among the four clusters clearly shows.

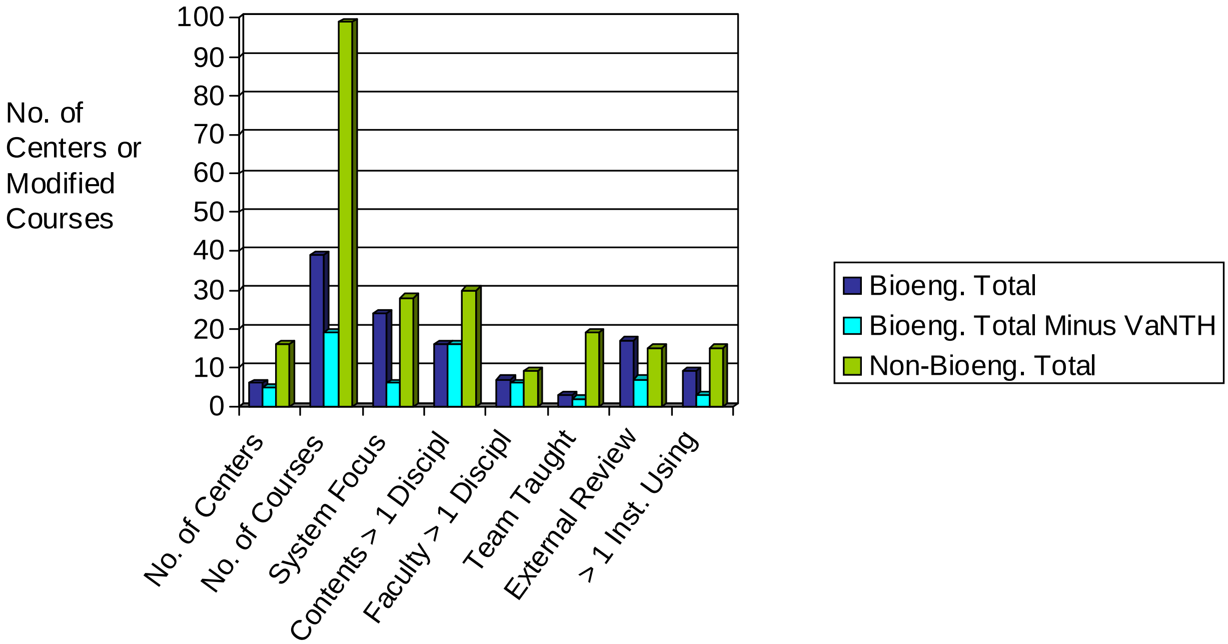

Figure 5 (a)
Modified Courses: Bioengineering vs Non-Bioengineering Centers

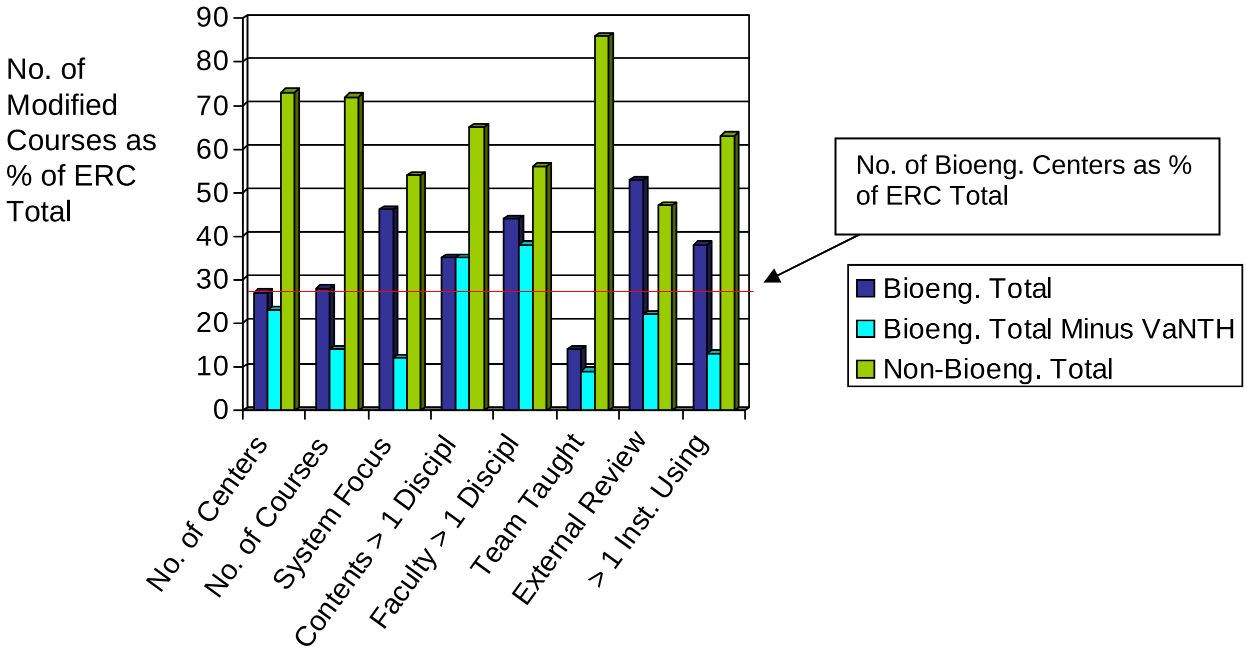

Figure 5 (b)
Modified Courses: Bioengineering vs.
Non-Bioengineering Centers as % of ERC Total

f. Comparative Study of Manufacturing/Processing and Non-Manufacturing/Processing ERCs

The contributions to the production of new and modified courses by the Manufacturing/Processing (Manuf/Proc) cluster are shown in Figures 6 and 7. In each figure, the information is presented in absolute numbers as well as percentages for Manuf/Proc and non-Manuf/Proc centers. As noted in Sec. 3 and Fig. 4(b), there are 5 centers in this cluster, together making up 23% of the center population.

From Figs. 6(a), 6(b), 7(a) and 7(b), the following observations may be made:

a. The output from the Manuf/Proc cluster is just over 20 new courses (Fig. 6(a)) and about 15 modified courses (Fig. 7(a)), or 15% and 10%, respectively of the productivity of the ERC Program total (Fig. 6(b) and Fig. 7(b)). Both these numbers are below the 23% share of the Manuf/Proc center population.

b. For new courses, except for "External Review" the education attributes of the Manuf/Proc. cluster fall in the range 10% - 20%, below its share in center population of 23%.

c. For modified courses, the Manuf/Proc cluster produces 50% of the ERC courses in which team teaching is used. In all other categories, the productivity of this cluster falls in the range of 0% to about 10% (Fig. 7(b)), below its 23% share of center population.

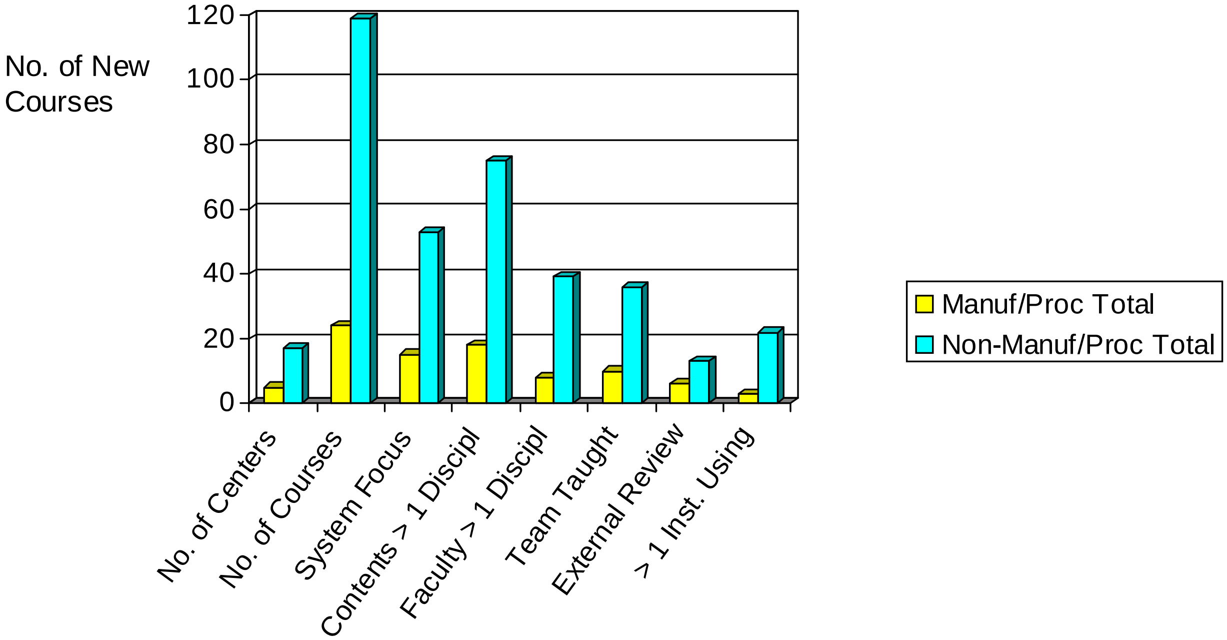

Figure 6 (a)
New Courses: Manufacturing/Processing vs
Non- Manufacturing/Processing Centers

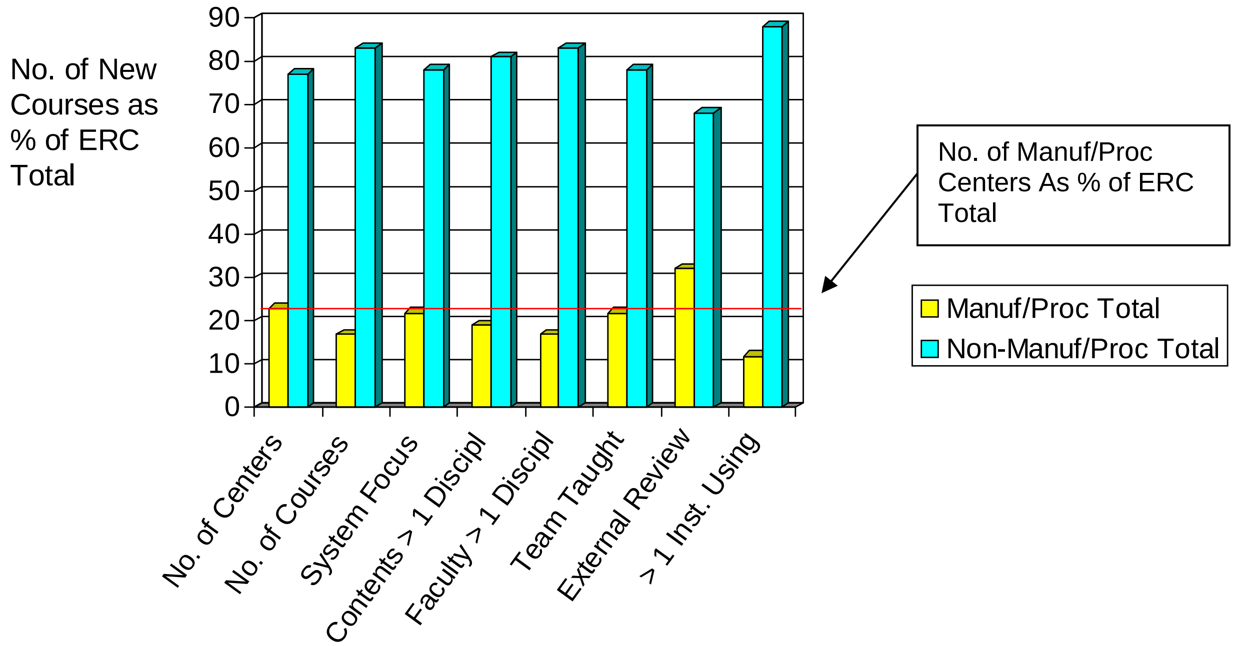

Figure 6 (b)
New Courses: Manufacturing/Processing vs
Non- Manufacturing/Processing Centers
as Percent of ERC Total

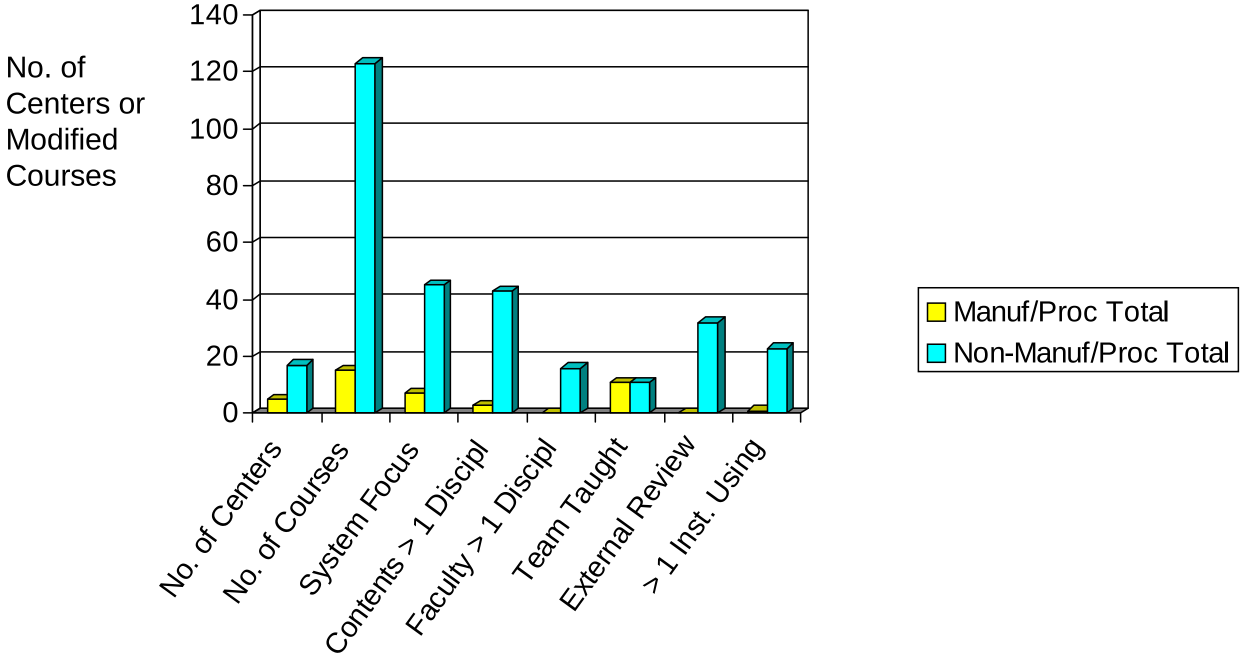

Figure 7 (a)
Modified Courses: Manufacturing/Processing vs
Non- Manufacturing/Processing Centers

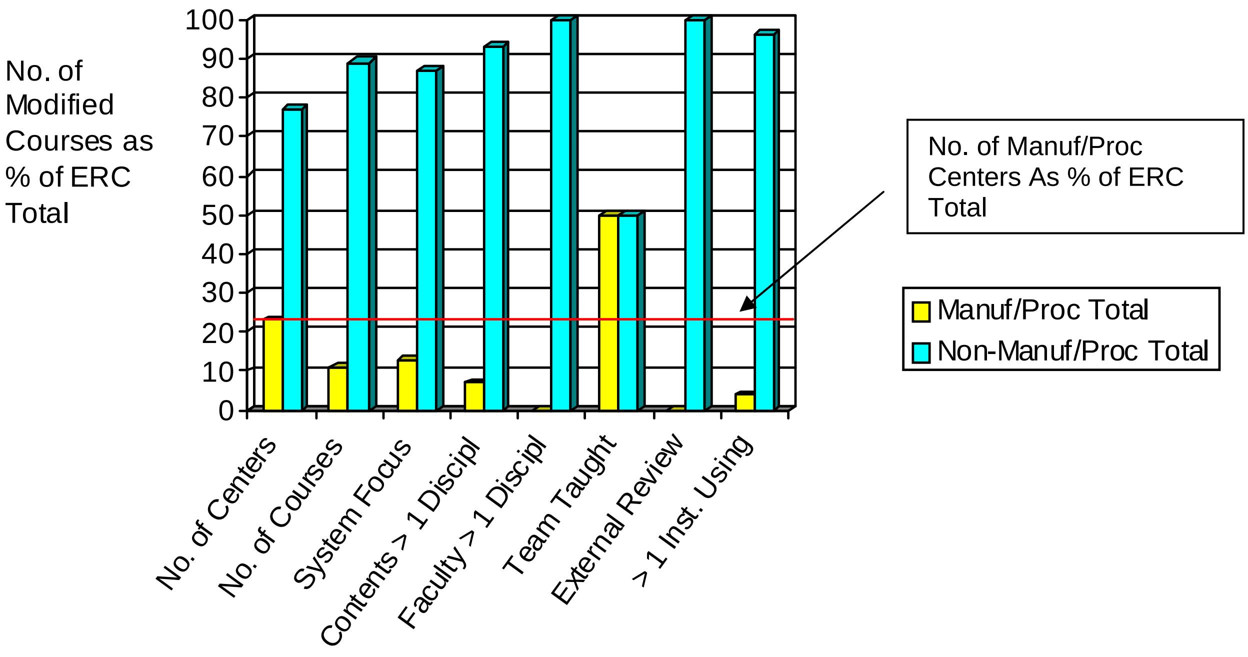

Figure 7 (b)
Modified Courses: Manufacturing/Processing vs
Non- Manufacturing/Processing Centers as Percent of ERC Total

g. Comparative Study of Earthquake Engineering and Non-Earthquake Engineering ERCs

A summary of the contributions to the production of new and modified courses by the Earthquake Engineering (“Earthquake”) cluster is given Figures 8 and 9. In Fig. 8(a) and Fig. 9(a), the information is presented in absolute numbers, whereas Fig. 8(b) and 9(b) provide the information as percentages of the ERC Program as a whole. As shown in Fig. 8(b) and Fig. 9(b), there are 3 centers in this cluster, making up 14% of the center population.

An examination of the information given in Figures 8(a), 8(b), 9(a) and 9(b) leads to the following conclusions:

a. The Earthquake cluster produces just over 10 new courses (Fig. 8(a)) or less than 10% of total ERC Program production (Fig. 8(b)), below the 14% share of Earthquake center population. On the other hand, the cluster produces about 35 modified courses (Fig. 9(a)), or about 25% of the total ERC output (Fig. 9(b), far exceeding its 14% share of center population.
b. For new courses, the Earthquake cluster attainment of ERC education attributes range below 10% in all 6 attributes (Fig. 9(b)), a level significantly below the 14% population share of the Earthquake cluster.
c. For modified courses, the Earthquake cluster is performing much better, besting its 14% population share in 3 education attributes while attaining about 10% in the remaining three attributes (Fig. 9(b)).

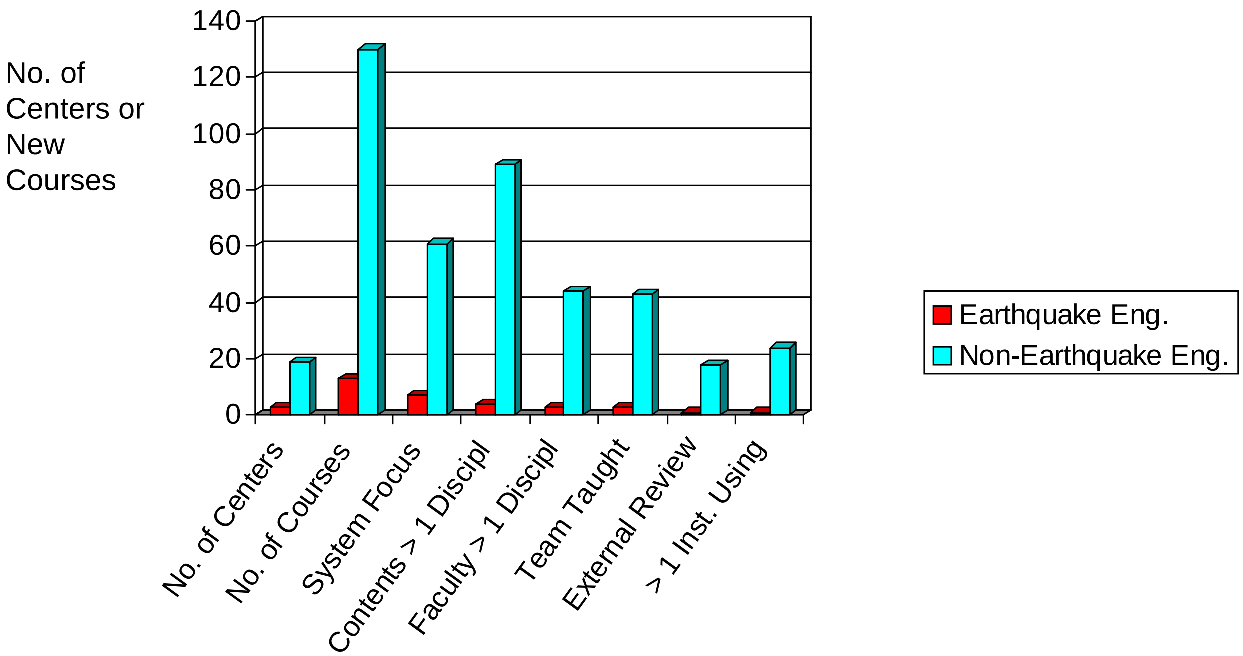

Figure 8 (a)
New Courses: Earthquake Engineering Centers vs Non-Earthquake Engineering Centers

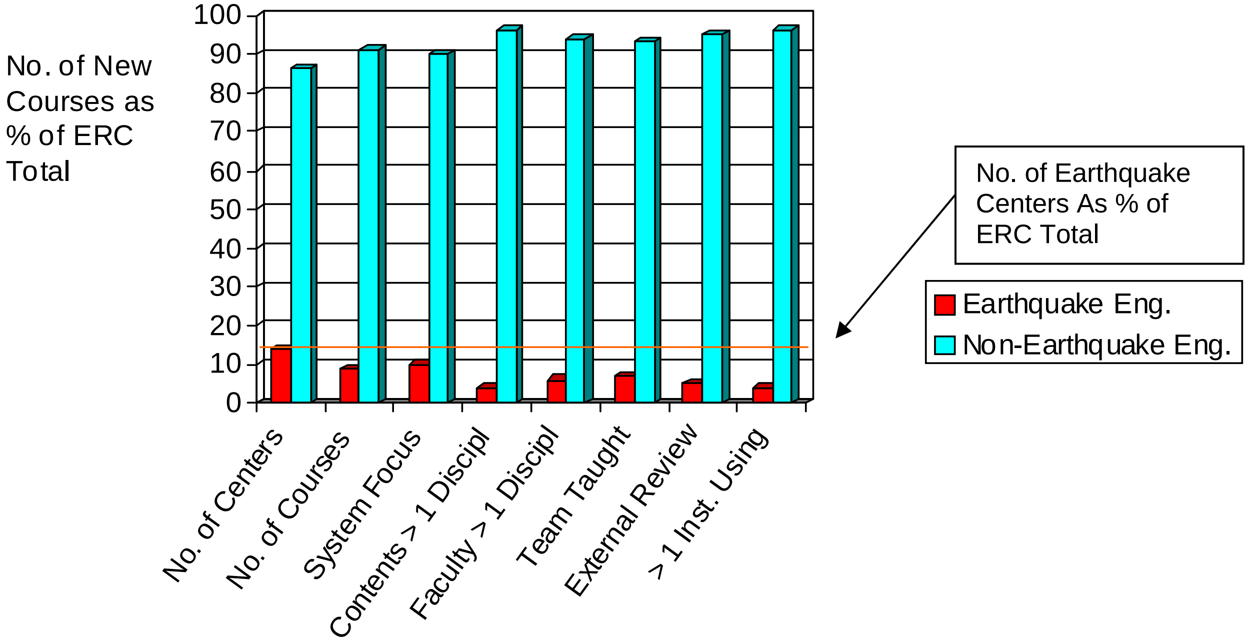

Figure 8 (b)
New Courses: Earthquake Engineering Centers vs Non-Earthquake Engineering Centers as Percent of ERC Total

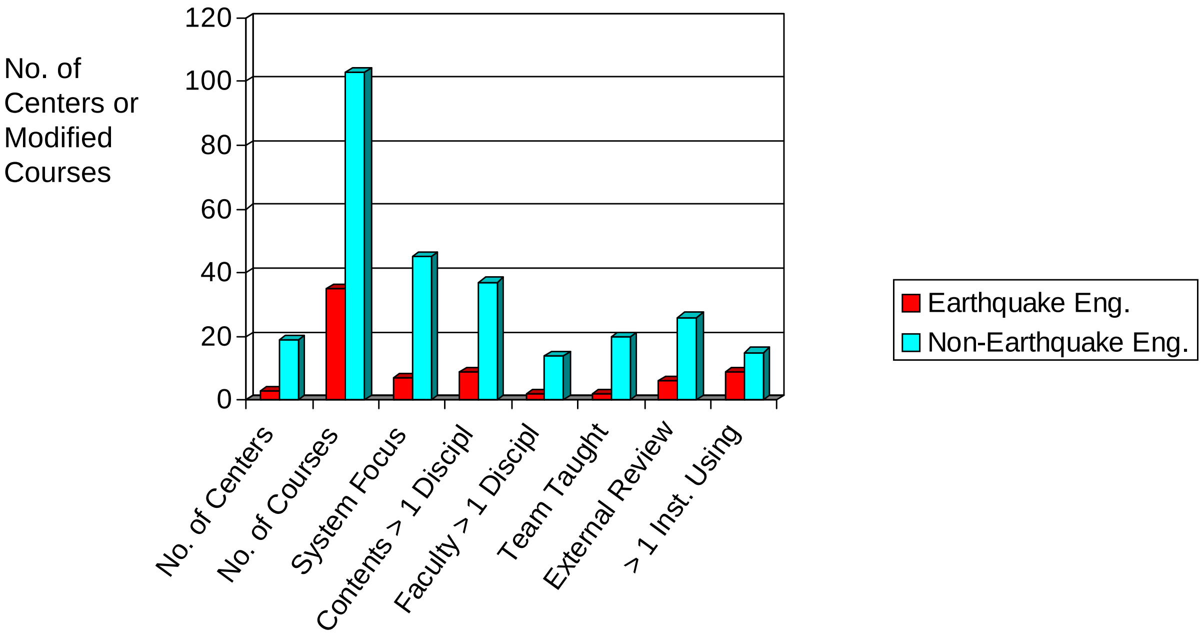

Figure 9 (a)
Modified Courses: Earthquake Engineering Centers vs. Non-Earthquake Engineering Centers

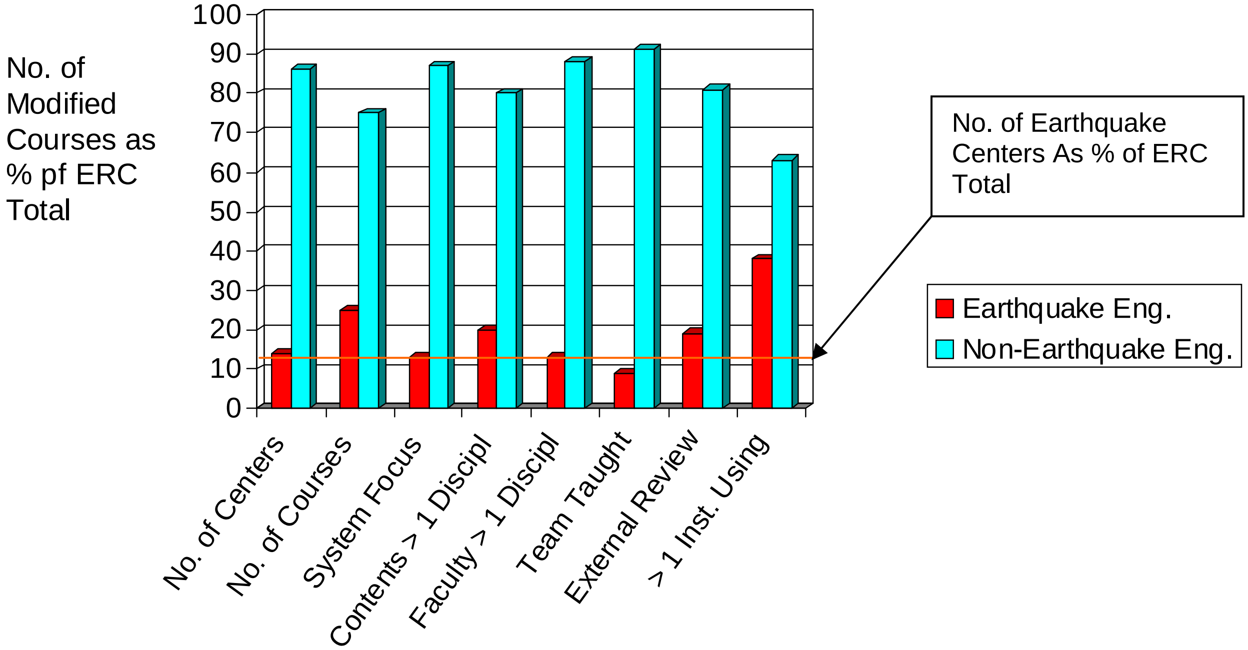

Figure 9 (b)
Modified Courses: Earthquake Engineering Centers vs.
Non-Earthquake Engineering Centers as Percent of ERC Total

h. Comparative Study of Microelectronic Systems and Information Technology (Micro/IT) and Non-Micro/IT ERCs

The Micro/IT ERC cluster has 8 centers comprising 36% of the ERC population. The production of new and modified courses by these centers is summarized in Figs. 10 and 11. The information is given in actual numbers in Fig. 10(a) and Fig. 11(a), respectively for new and modified courses, and in Fig. 10(b) and 11(b) as percentages of the total for the ERC Program as a whole.

Figures 10(a), 10(b), 11(a) and 11(b) lead to the following conclusions:

a. The Micro/IT cluster produces over 85 new courses (Fig. 10(a)) or over 60% of total ERC Program production (Fig. 10(b)), far in excess of its 36% share of ERC center population. In addition, the cluster produces close to 50 modified courses (Fig. 11(a)), or 36% of the total ERC output (Fig. 11(b), exactly matching the Micro/IT share of 36% of center population.
b. For new courses, the Micro/IT cluster achievement in attaining ERC education attributes range from more than 50% to close to 70%, exceeding the cluster's population share of 36% by a wide margin in all categories of the education attributes (Fig. 10(b)).
c. For modified courses, the Micro/IT Cluster is the leader in 5 out 6 attributes, as discussed in Sec. 5.2. However, when viewed against the Cluster's population share, Micro/IT has a mixed record. In two of these attributes, viz. multidisciplinary

contents and multidisciplinary faculty, the cluster is at about 40%, slightly exceeding its population share of 36%, but the cluster's productivity in the remaining four attributes fall below its population share (Fig. 11(b)).

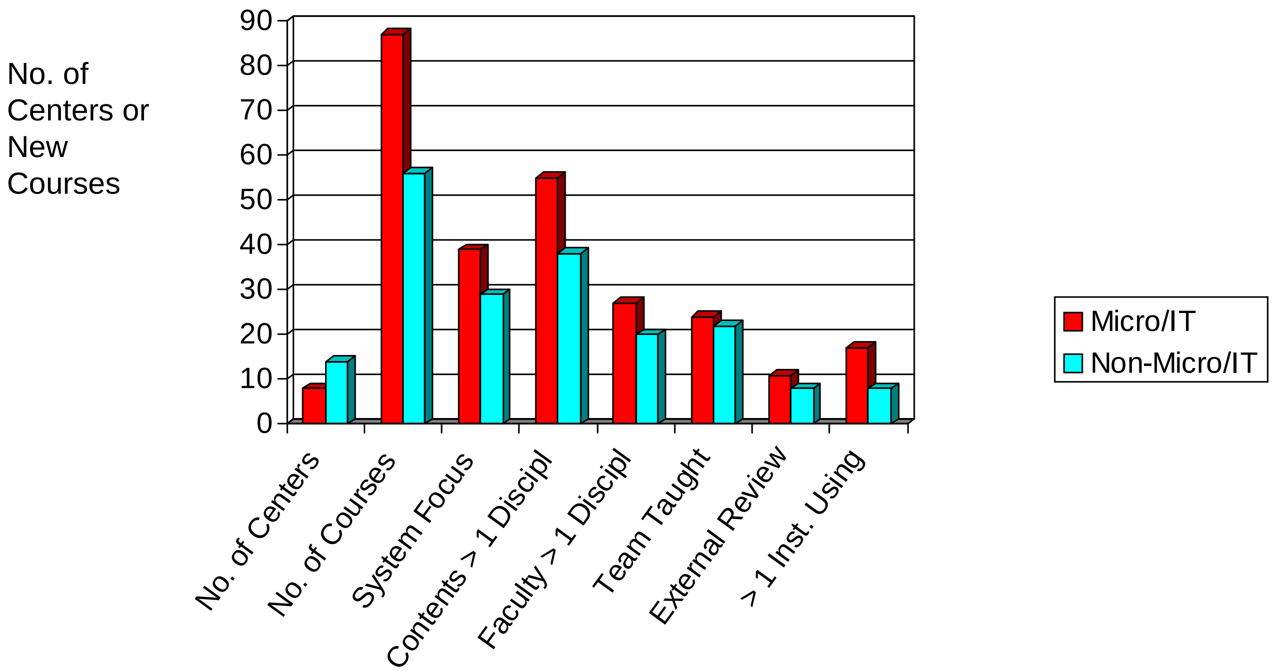

Figure 10 (a)
New Courses: Micro. Systems and IT Centers vs Non- Micro. Systems and IT Centers

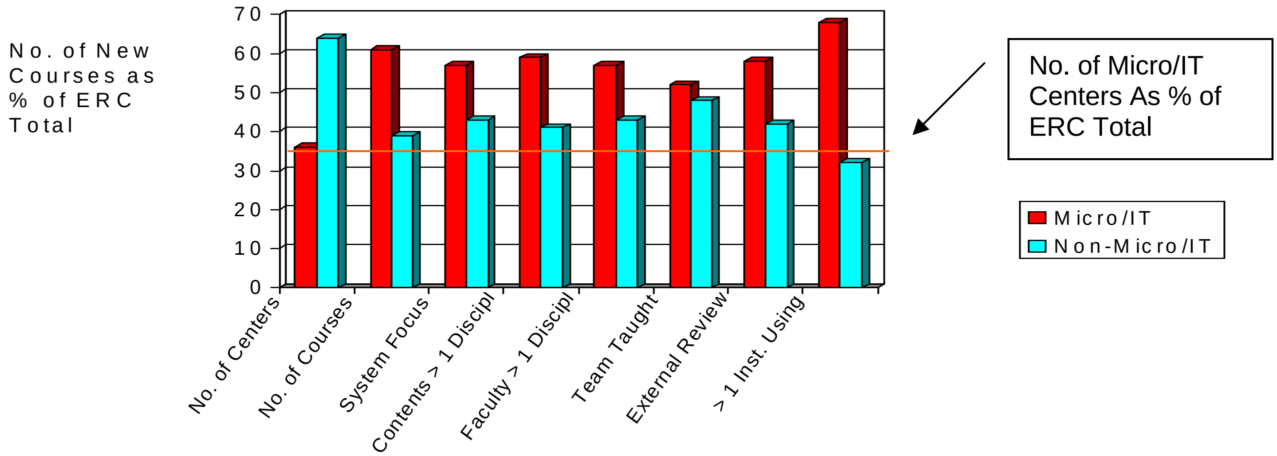

Figure 10 (b)
New Courses: Micro. Systems and IT Centers vs Non- Micro. Systems and IT Centers as Percent of ERC Total

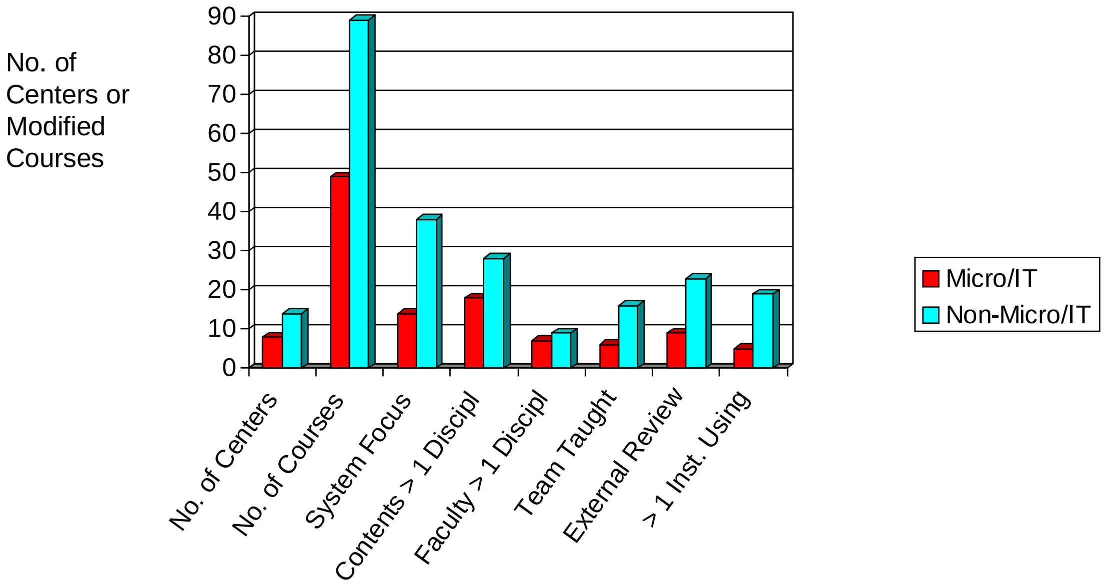

Figure 11 (a)
Modified Courses: Micro. Systems and IT Centers vs Non- Micro. Systems and IT Centers

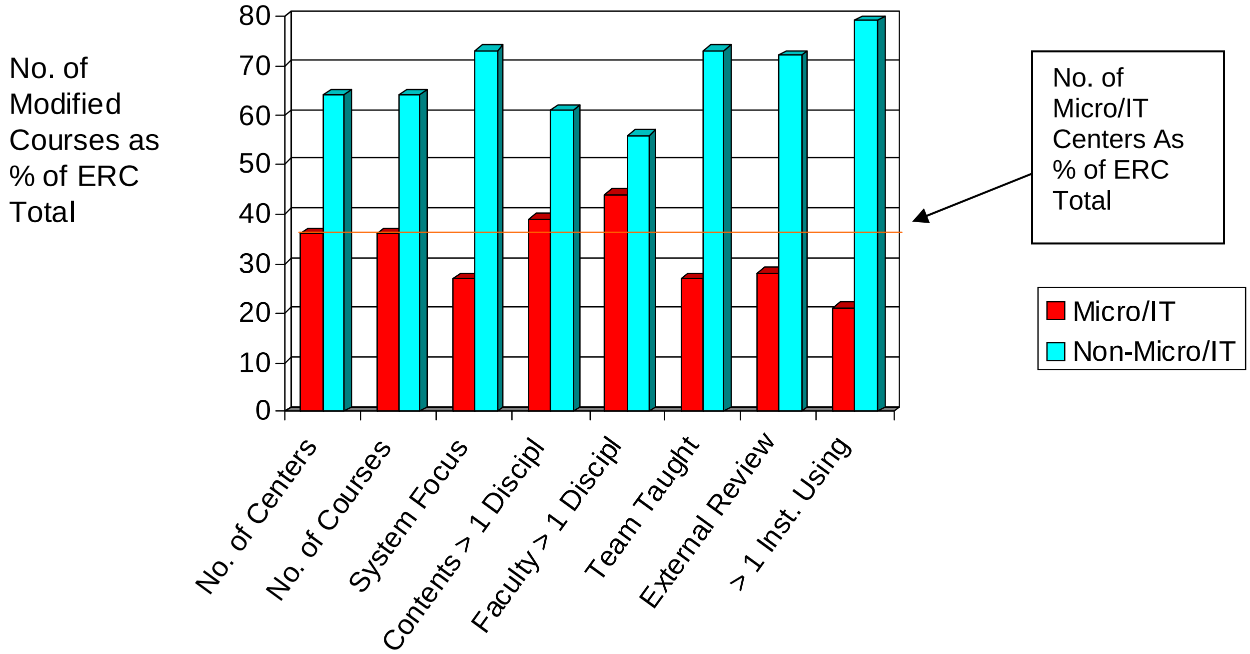

Figure 11 (b)
Modified Courses: Micro. Systems and IT Centers vs.
Non- Micro. Systems and IT Centers as Percent of ERC Total

6. Activity Index of the Clusters

The number of centers in each of the four ERC clusters ranges from a low of 3 for Earthquake to a high of 8 for Micro/IT. This is one reason why the results presented in Sec. 5.5 through Sec. 5.8 show such a variation of activity output among the clusters.

In the present study, two methods have been employed to provide a more accurate comparison of activity output by the clusters. Results from the first method have been discussed in Sec. 5.1. In the present section, the second method will be discussed. For this purpose, we normalize the percentage activity output (PAO) presented in Figs. 4 – 11 by the percent share (PS) of cluster population. As shown in the Appendix 2, the percent shares are as follows:

Bioengineering: PS = 27%
Manuf/Proc: PS = 23%

Earthquake: PS = 14%
Micro/IT: PS = 36%

We define the ratio of PAO to PS as the Activity Quotient or AQ. That is,

AI = PAO/PS

In this study, AI is expressed as a decimal. A cluster that has activity output that matches its center population share in the ERC Program will have AI = 1. If AQ is less than 1, the cluster is not producing its "fair share" or load of the education activities. AI > 1 means the total education activity output of the cluster is above the number one would expect based on its population share.

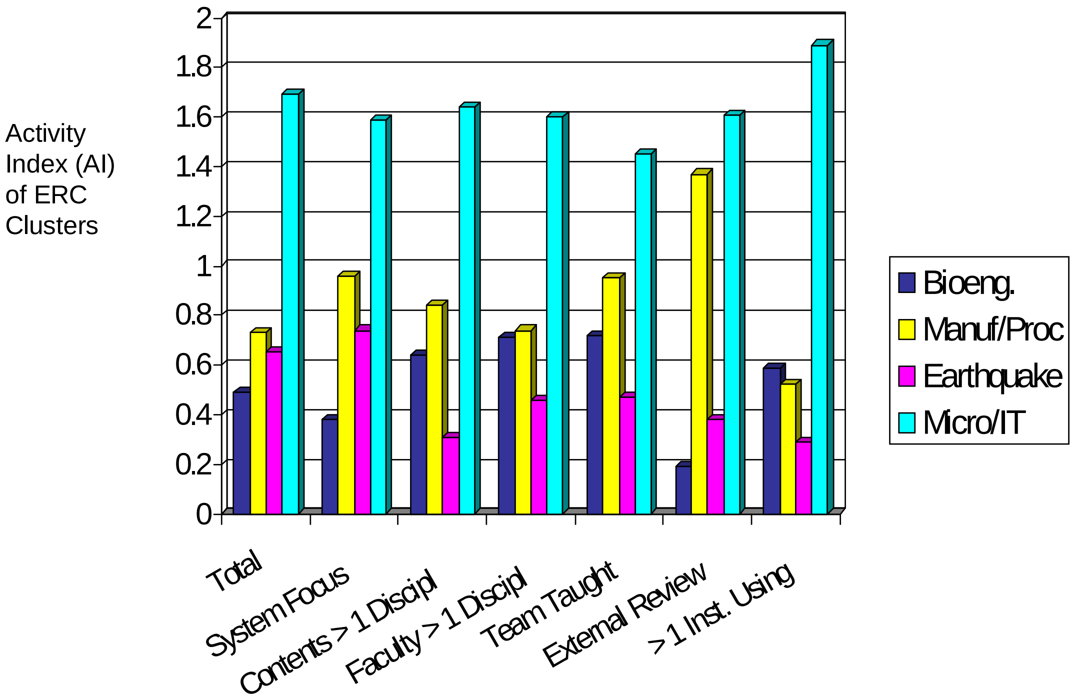

Figure 12 (a)
New Courses: Comparison of Activitiy Index for Clusters

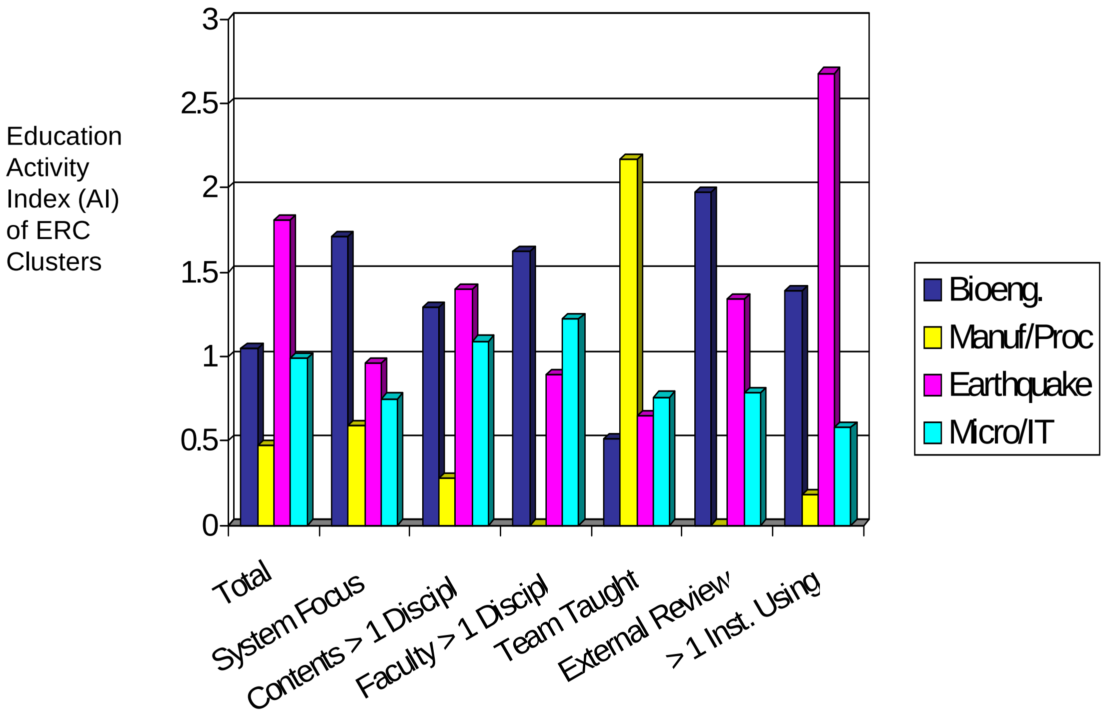

Figure 12 (b)
Modified Courses: Comparison of Activitiy Index for Clusters

In Fig. 12(a) and Fig. 12(b), a comparison the values of AI for the ERC clusters is given for the total number of activities and for the 6 ERC education attributes. For new courses, the superior productivity of the Micro/IT cluster is clearly evident, with its value of AI far exceeding the value 1 in both total course production as well as the production courses possessing the ERC education attributes.

For modified courses, scores for the Bioeng. Cluster exceed the value 1 in 6 of the 7 categories, falling to 0.5 in the "Team Taught" category. The Earthquake Cluster also scores relatively well with AI > 1 in 4 of the 7 categories.

The factors that lead to these differences deserve attention, but they are outside of the scope of this phase of the present study. Similarly, AI may be used to compare the productivity between centers, but it is not within the scope of the current study.

7. Single-Institution Centers (SICs) vs. Multi-Institution Centers (MICs)

The productivity of SICs and MICs in new and modified courses is presented in Figs. 13 and 14, respectively. For new courses, Fig. 13(a) presents the data in absolute numbers whereas Fig. 13(b) gives the information as percentages of the total production by the ERCs. Figures 14(a) and 14(b) similarly present the data for modified courses.

In Appendix 2 the centers that are single-institution centers (SICs) and multi-institution centers (MICs) are listed. The 7 SICs constitute 32% of the ERC population (that is the SIC population share is 32%), while the 15 MICs represent 68% of the total center population of 22 centers.

The general observations that may be made about the productivity of the SICs and MICs are as follows:

a. The SICs produces about 50 new courses (Fig. 13(a)) or over 35% of total ERC Program production (Fig. 13(b)), slightly exceeding their 32% share of ERC center population. In addition, the SICs produced about 25 modified courses (Fig. 14(a)), or close to 20% of the total ERC output (Fig. 14(b) of modified courses, far below the SICs share of 32% of center population.
b. For new courses, the SICs productivity in 4 out of 6 categories (Fig. 13(b)) is approximately equal to or exceeds their population share (32%). That is, in each of the 4 categories, the SICs production of courses that have the ERC education attribute is at a level that is at least the same as their population share. In the remaining two categories, viz. External Review and use by multiple institutions, the SICs have only 10% and 5%, respectively, of the modified courses that possess these attributes.

   Thus, in new courses, the MICs outperforms the SICs in the production of courses that possess the ERC education attributes.

c. For modified courses, the SICs perform below their population share in all attributes except one, and that is team teaching where the SICs have produced 55% of the ERC modified courses (Fig. 14(b)).

   This leads to the conclusion, as in new courses, the MICs have outperformed the SICs on the production of courses that possess the ERC education attributes.

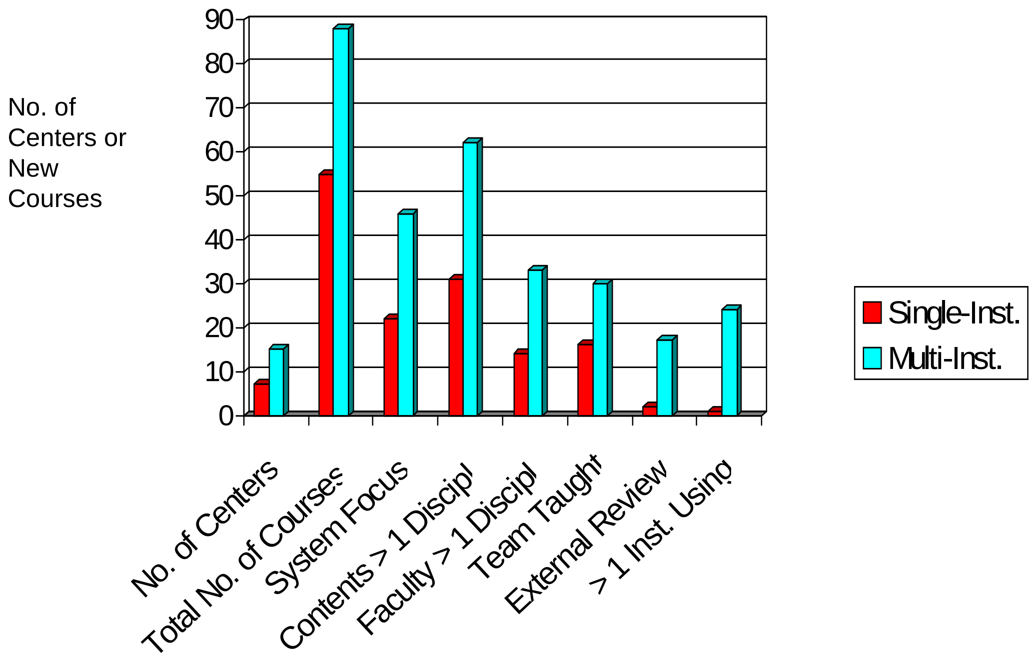

Figure 13 (a)
New Courses: Single-Institution vs. Multi-Institutional Centers

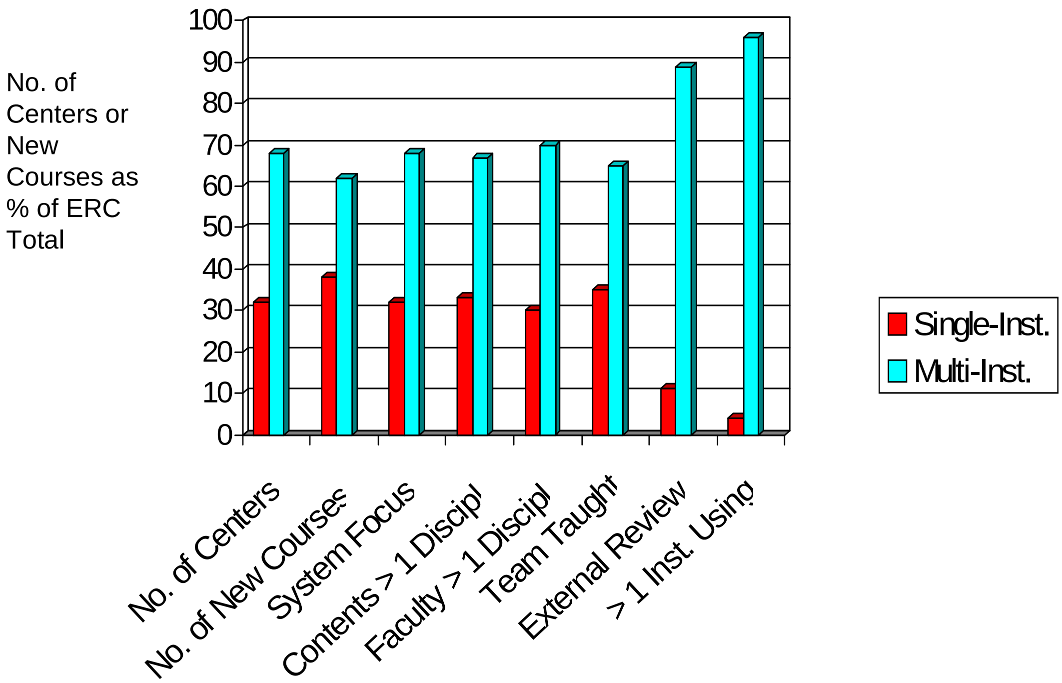

Figure 13 (b)
New Courses as Percent of Total ERC New Courses:
Single-Institution vs. Multi-Institutional Centers

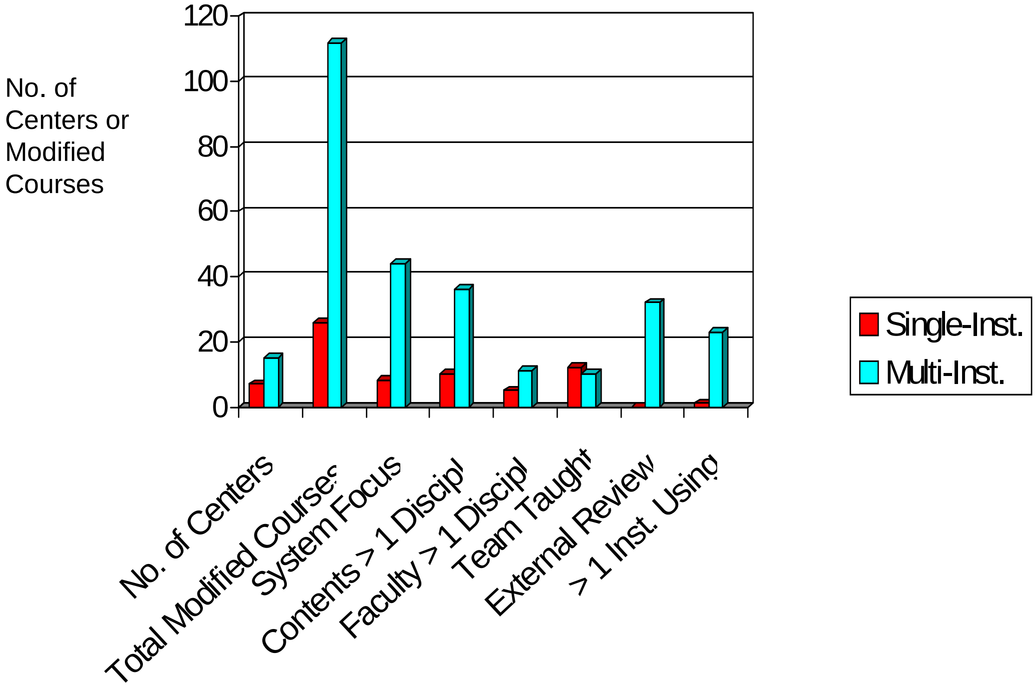

Figure 14 (a)
Modified Courses: Single-Institution vs. Multi-Institutional Centers

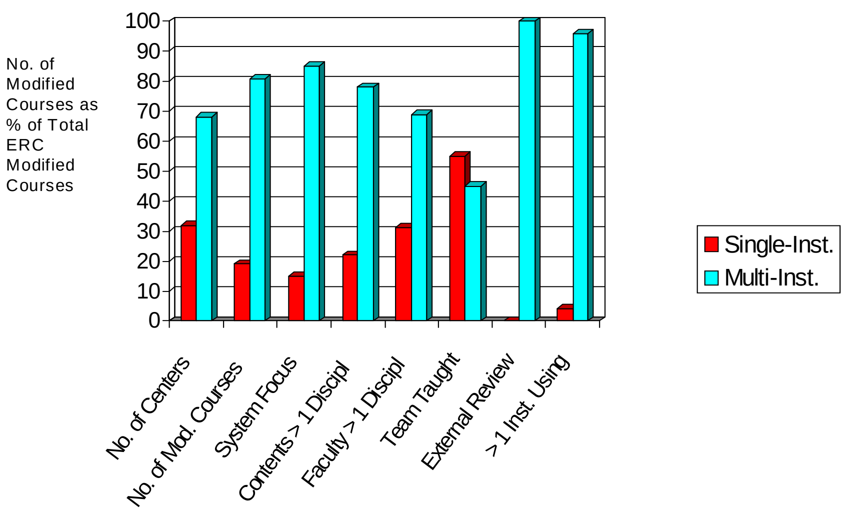

Figure 14 (b)
Modified Courses as Percent of Total ERC Modified Courses:
Single-Institution vs. Multi-Institutional Centers

8. Influence of the Age of a Center

It is instructive to examine the question of whether the longer a center is funded, the higher is its productivity. The particular issue here is: Do older centers have more success in incorporating the ERC attributes in their education innovations? This indeed is shown by the data; however, there are a few surprises, as the performance of the centers varies between new and modified courses, as will be discussed.

In this study, centers that are 2-5 years into their funding cycle in 2005 are considered new centers, designated by 2-5YCs, while 6-10 years centers are classified as old centers, denoted by 6-10YCs.

The productivity of 2-5YCS and 6-10YCS in new and modified courses is presented in Figs. 15 and 16, respectively. For new courses, Fig. 15(a) presents the data in absolute numbers whereas Fig. 15(b) gives the information as percentages of the total productivity of the ERCs. Figures 16(a) and 16(b) similarly present the data for modified courses.

As has been noted in Sec. 3, there are five (5) 2-5YCs in the ERC Program, comprising 23% of the center population. The remaining centers 17 centers, the 6-10YCs, constitute 77% of the population.

Using the information contained in Figs. 15(a), 15(b), 16(a) and 16(b), the following conclusions may be drawn:

a. The 2-5YCs have produced over 30 new courses (Fig. 15(a)) or over 20% of the total ERC production of 143 new courses (Fig. 15(b)). By contrast, the 6-10YCs have produced about 110 new courses, or about 77% of the ERC total. These percentages are almost identical to the respective population shares of the 2-5YCs and 6-10YCs.

b. For new courses, there are no major deviations by the 2-5YCs and 6-10YCs from their respective population shares in their production of courses that possess the ERC education attributes, except in two of them, viz., External Review and multiple institution usage. In the former, the 2-5YCs produce only 5% of the total ERC output (Fig. 15(b)), significantly below the population share (23%) of these centers. By contrast, the 6-10YCs produce 95% of the total ERC output. For courses that have been adopted by more than one institution, the output of the 2-5YCs and 6-10YCs are about even at 50% (Fig. 15(b)).

   One may, therefore, conclude that, overall, the 6-10YCs have only a slight edge in producing new courses that possess the ERC attributes.

c. For modified courses, the 2-5YCs have produced close to 40 courses (Fig. 16(a)), or close to about 29% (Fig. 16(b)) of the ERC total of 138 modified courses. The production by the 6-10YCs is close to 100 courses (Fig. 16(a)) or slightly over 70% of the total (Fig. 16(b)). The 6-10YCs outperform their population share of 77% in their production of

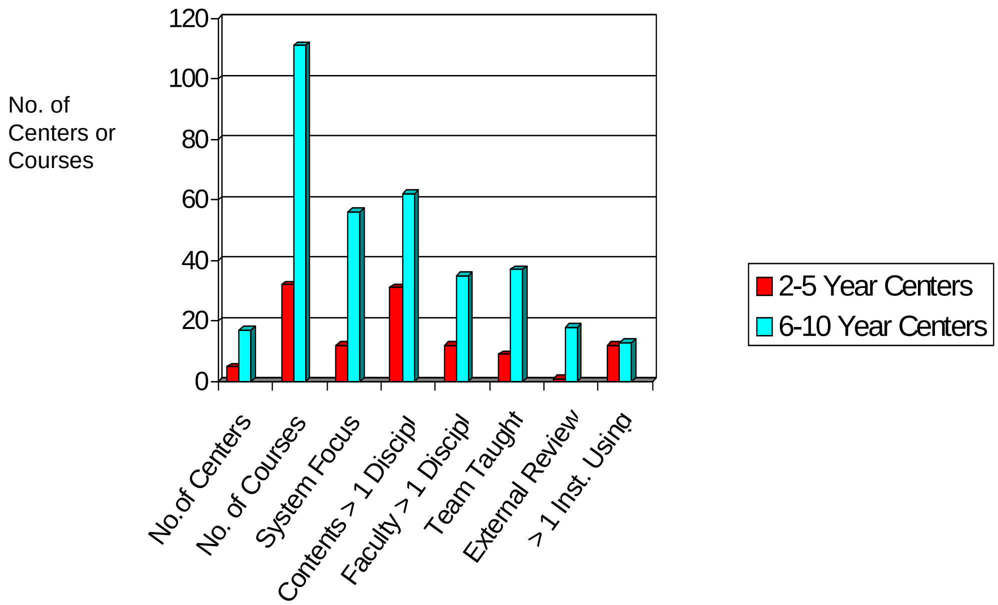

Figure 15(a)
No. of Centers or New Courses: 2-5 Years Centers vs 6-10 Years Centers

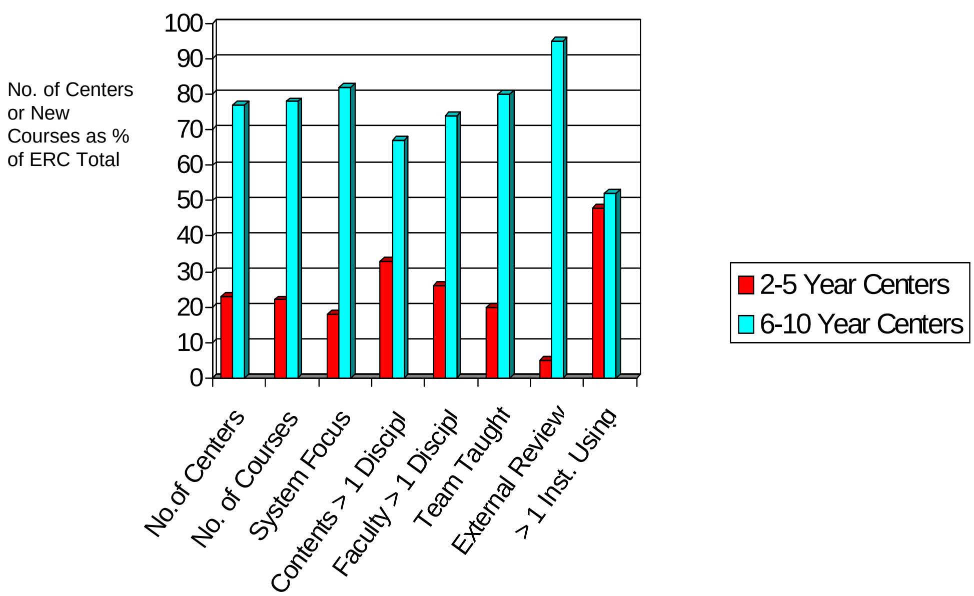

Figure 15(b)
Number of Centers or New Courses as Percent of ERC Total: 2-5 Years Centers vs 6-10 Years Centers

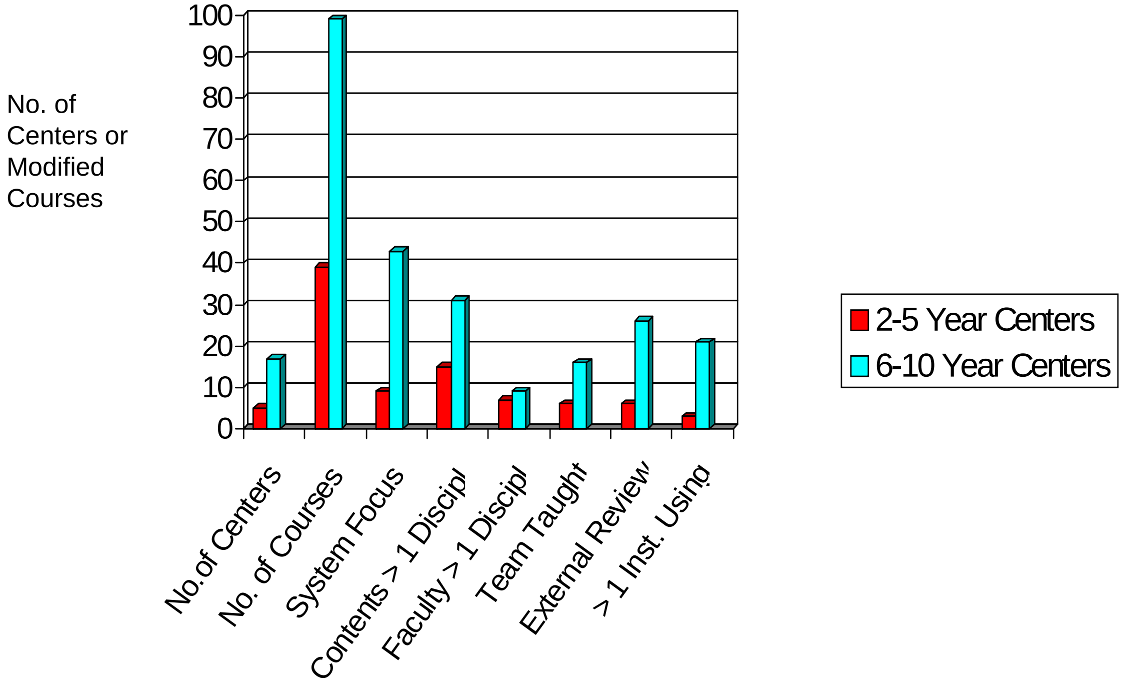

Figure 16 (a)

No. of Centers or Modified Courses: 2-5 Years Centers vs 6-10 Years Centers

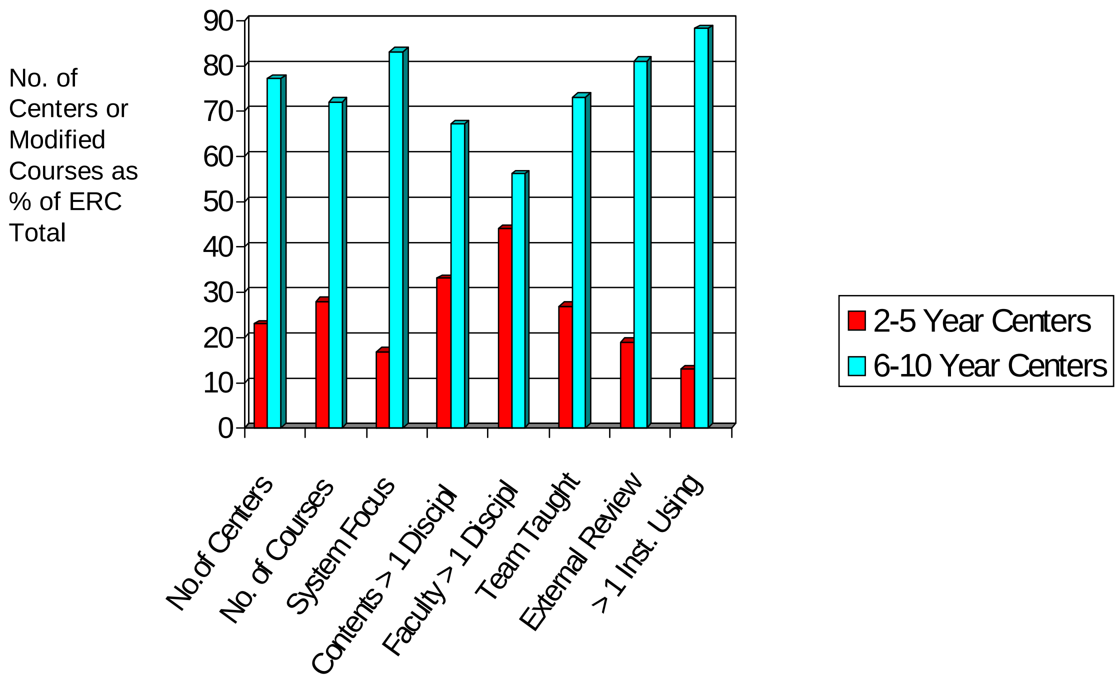

Figure 16 (b)

No. of Centers or Modified Courses as Percent of ERC Total:
2-5 Years Centers vs 6-10 Years Centers

modified courses that possess the ERC education attributes in three of the six categories, viz. System Focus, External Review, and "> 1 Inst. Using." The 6-10YCs under-perform in Contents > 1 Discipl", "Faculty > 1 Discipl." and "Team Taught".

There is, therefore, no clear distinction between 2-5YCs and 6-10YCs in their production of modified courses that possess the ERC education attributes.

From the discussion in the last paragraphs of (b) and (c) above, it may be concluded that the age of a center has only minimal effect on the ERCs' production of either new or modified courses that have the ERC education attributes. Current data show that it is in the early phases of funding that a center is particularly effective in producing courses that possess the ERC education attributes.

9. Discussion and Conclusions

In this report, we have presented the results of a study conducted by the ERC Education Assessment/Dissemination Task Group. In the study we have examined the education activities in the NSF ERCs presented a summary of data on the accomplishments and productivity of the ERCs in education activities at the undergraduate and graduate levels. A comparison has been made at the cluster level but, in keeping with the charge to the Task Group, we have made no attempt at assessing or comparing the performance of individual centers.

We have focused on the following data: new and modified courses; new major and minor emphases; new certificate programs; and new degree programs. An additional focus of the study is on new and modified courses that possess the desired ERC education attributes. It is found that the ERCs are quite successful in introducing a system focus and multidisciplinary contents into their courses, but are less successful in integrating the remaining four ERC education attributes into the courses, these attributes being the inclusion of more than one discipline in the faculty teaching the course; team teaching; having courses reviewed by an external body (although in the case of graduate courses, no such review is necessary); and having more than one institution adopting the course.

A comparison of the total output of the ERCs categorized according to technological clusters has been examined to provide an insight into their absolute and relative productivity. It is found that the Microelectronics and Information Technology (Micro/IT) Cluster, the largest among the 4 clusters with 8 centers, leads in the production of new courses but has a mixed record on modified courses in terms of meeting the desirable attributes of the ERC Program. This cluster also plays a dominant role in the production of courses that possess the desired education attributes of the ERC Program. Specifically, the Micro/IT Cluster has produced 60% of the new courses, with the remaining three clusters trailing at between less than 10% to about 15%. For modified courses, the Micro/IT cluster also leads with 35% in overall course production, but the Bioengineering Cluster is also an important producer of courses in this category. Results comparing the output of each cluster with that of the rest of the centers have been detailed in the report.

Taking into account the population share of the centers in each cluster, we have employed per center data and an Activity Index (AI) to probe cluster productivity. The results show variability across clusters as well as between new and modified courses. Whether the variability is random or caused by deliberate planning on the part of the centers is currently unknown. For example, some centers in a given technological cluster may choose to focus on developing modified courses instead of new courses, or *vice versa*. The activity index could be also used to examine the relative productivity of individual centers. These topics are outside of the scope of the current phase of this study but deserve to be investigated.

It is not too surprising that multiple-institution centers has outperformed single-institution centers in producing both new and modified courses that possess the ERC education attributes. Here again, it will be instructive to examine the information beneath the cluster level, to examine contributions by individual centers within each cluster, to uncover any pattern. This level of examination is outside the current phase of the present study.

Available data show that the age of a cluster has only minimal effect on the ERCs' ability to produce courses that have the ERC education attributes. Centers could very well decide to start a few courses, and then continue to work on them to improve them, instead of starting work on other courses. Though outside the scope of the present study, here too it would be instructive to study how true this conclusion applies across the centers within any specific cluster.

Finally, it would be worthwhile to probe the evolving trend among the centers in terms of their education focus and productivity. The significance of integrating research and education activities in research centers is being increasingly recognized. Furthermore, centers in the ERC Program are increasingly embracing the opportunity to make a lasting impact in the nations' research and education enterprise through their efforts in education. These factors are contributing to a continually changing landscape for the education activities of centers in the ERC Program, a landscape that deserves our attention.

10. Acknowledgements

We wish to acknowledge with gratitude the contributions made by the faculty and administrative staff of the ERCs, especially the Center Directors and Education Directors, in preparing their education reports. The contributions made in this study by Gary Gabriele and Lynn Preston, Division Director and Deputy Division Director of the Division of Engineering Education and Centers at NSF, respectively, are also gratefully acknowledged.

11. References

1. Various ERC Program Solicitations issued by NSF to solicit new proposals, the latest being: "Engineering Research Centers (ERC): Partnerships in Transforming Research, Education and Technology," Program Solicitation NSF 04-570 (Replaces Document NSF 02-24).
   Available: http://www.nsf.gov/pubs/2004/nsf04570/nsf04570.htm

2. ERC Program Annual Report Guidelines (Revised June, 2006):

http://chaffee.qrc.com/nsf/eng/ercweb/help/rpt_guide/2006_Reporting_Guidelines.doc

3. ERC Program's Performance Review Criteria: http://chaffee.qrc.com/nsf/eng/ercweb/help/evaluation_matrix_ii.xls

Appendix 1: ERC Education Assessment/Dissemination Task Group

Formation, Purpose and Charge

Formation

Effective October 15, 2004, the ERC Education Assessment/Dissemination Task Group has been formed to assist the ERC Program in its assessment and dissemination activities. Members of the EAD Task Group are appointed by the Coordinator for the ERC Program, and serve nominal one-year terms that are renewable. Members are selected from within and outside the ERCs and EERCs.

Purpose

The objectives in the formation of the EAD Task Group are:

a. To assist NSF in documenting and categorizing education innovations produced by the ERCs and EERCs.
b. To assist NSF in investigating, assessing and calibrating the relative education achievements of research fields represented by clusters of centers.
c. To assist NSF in determining effective mechanisms of disseminating ERC-EERC education innovations.
d. To provide guidance to NSF on means to improve assessment and dissemination of ERC and EERC education innovations.
e. To employment assessment as a tool to promote feedback to ERCs/EERCs and NSF to effect continuous improvement.

Charge

The EAD Task Group is charged with the following specific tasks:

a. The EAD Task Group shall provide general advice and specific input, upon request, to the ERC Program in its ERC-EERC Education Assessment/Dissemination Study. The advice and input shall be verbal and/or in writing.
b. The advice and input that the EAD Task Group provides shall cover education innovations pertaining to the undergraduate and graduate levels, including new degree programs, new courses and related curricular materials, but shall not include education outreach and research experiences for students.
c. In carrying out their duties related to this Task Group, members shall attend meetings, workshops, and onsite visits as needed from time to time.
d. The EAD Task Group shall work directly with the ERC Program, for which the principal liaison shall be the Coordinator for ERC Education Program.

Appendix 2: Centers Providing Education Reports

As of April 25, 2006, all twenty-two centers had submitted education reports. These respondents, indicated with the lead institutions, names of centers, and year of inception, are:

a. GaTech – Georgia Tech/Emory Center for the Engineering of Living Tissues (GTEC, est. 1998)
b. JHU – Computer-Integrated Surgical System and Technology (CISST, est. 1998)
c. MIT – Biotechnology Process Engineering Center (BPEC, est. 1985)
d. U. of Washington – University of Washington Engineered Biomaterials ERC (UWEB, est. 1996)
e. USC – Biomimetic MicorElectronic System (BMES, est. 2003)
f. Vanderbilt U. –Vanderbilt ERC for Bioengineering Educational Technologies (VaNTH, est. 1999)
g. U. of Arizona – Center for Environmentally Benign Semiconductor Manufacturing (CEBSM, est. 1996)
h. Clemson U. – Center for Advanced Engineering Fibers and Films (CAEFF, est. 1998)
i. U. of Florida – Particle Engineering Research Center (PERC, est. 1994)
j. U. of Kansas – Center for Environmentally Beneficial Catalysis (CEBC, est. 2003)
k. U. of Mich. – ERC for Reconfigurable Manufacturing Systems (RMS, 1996)
l. Colorado St. U. – Extreme Ultraviolet Science and Technology (EUV, est. 2003)
m. U. of Illinois – Mid-America Earthquake Center (MAE, est. 1997)
n. U. of Mass. – Collaborative Adaptive Sensing of the Atmosphere (CASA, est. 2003)
o. Northeastern U. – Center for Subsurface Sensing and Imaging Systems (CenSSIS, est. 2000)
p. USC – Integrated Media Systems Center (IMSC, est. 1996)
q. VPI – Center for Power Electronics Systems (CPES, est. 1998)
r. Buffalo – Multidisciplinary Center for Earthquake Engineering Research (MCEER, est. 1997)
s. UC (Berkeley) – Pacific Earthquake Engineering Research Center (PEER, est. 1997)
t. CalTech – Center for Neuromorphic Systems Engineering (CNSE, est. 1986)
u. GaTech – Packaging Research Center (PRC, est. 1994)
v. U. of Mich. – Wireless Integrated Microsystems (WIMS, est. 2000)

The first six centers (a – f) comprise the Bioengineering Cluster (Bioeng.) of the ERC Program (i.e., 6 out of 22 centers or 27% of total).

The other ERC clusters are:

Manufacturing and Processing (Manuf/Proc): (g), (h), (i), (j), (k) (23% of total).
Earthquake Engineering (Earthquake): (m), (r), (s) (14% of total).
Microelectronic Systems and Information Technology (Micro/IT): (l), (n), (o), (p), (q), (t), (u), (v) (36% of total).

The seven single-institution centers are: MIT-BPEC (c); U. of Washington – UWEB (d); U of Florida – PERC (i); USC-IMSC (p); U. of Mich. – RMS (k); CalTech – CNSE (t); and GaTech – PRC (u).

The following fifteen (15) centers are multi-institution centers: (a), (b), (e), (f), (g), (h), (j), (k), (l), (m), (n), (o), (q), (r) and (s).

The five (5) new centers, defined in this study as those centers that that were within 2-5 years (2-5YC) of operation as of the year 2005, are: USC-BMES (e); U. of Kansas – CEBC (j); Colorado St. U. – EUV (l); U. of Mass – CASA (n); and Northeastern U. – CenSSIS (o).

Centers in their 6-10 years of funding (6-10YC) as of 2005 are classified in this study as "old centers." There are seventeen (17) of them: (a), (b), (c), (d), (f), (g), (h), (i), (k), (m), (p), (q), (r), (s), (t), (u), and (v).

Appendix 3: Technology Clusters and Course Activities

Cluster	No. of Centers	New and Modified Courses		New Courses		Modified Courses	
		Total	Cluster Average	Total	Cluster Average	Total	Cluster Average
Bioengineering:	6	58	9.67	19	3.17	39	6.50
Manufacturing and Processing:	5	39	7.80	24	4.80	15	3.00
Earthquake Engineering:	3	48	16.00	13	4.33	35	11.67
Micro. Sys./IT:	8	136	17.00	87	10.88	49	6.13