Accommodating an Expanding Curriculum with Limited Resources[1]

Timothy A. Johnson, Richard L. Goldberg, Stephen R. Quint, Charles C. Finley, Henry S. Hsiao, Stephen B. Knisley

"The test of a good teacher is not how many questions he can ask his pupils that they will answer readily, but how many questions he inspires them to ask him which he finds it hard to answer." (Alice Wellington Rollins, writer)

Abstract

Economic, institutional and expanding curricular needs are placing extraordinary demands on academic institutions engaged in biomedical research and education. In this paper, we describe a shared laboratory facility created on our campus that permits the extension of existing curricular offerings into laboratory-based instruction while simultaneously providing an opportunity for laboratory-based curricular expansion via group instruction. The modular design of the new curricular offerings and the shared facility that supports it provide unique teaching opportunities and versatile, adaptable course content. Our new laboratory currently supports five classes taught by three instructors and a newly, restructured sixth course team taught by six faculty within the department. The laboratory was created for less than $75K, while the restructured course cost nothing in terms of additional resources or faculty. Our model may address many of the emerging concerns for biomedical academicians.

Introduction

The landscape for engineering education, in general, and biomedical engineering, in particular, is in an unprecedented era of growth and restructuring. Projections by national monitors of engineering need and expertise [1][2] indicate that engineering demand overall will expand by 9.4% to fulfill anticipated needs in the next decade and that biomedical engineering, specifically, will grow by more than 31.4% through 2010. While biomedical engineers account for less than 1% of all engineering sub-specialties, it is noteworthy that this sub-specialty was first recognized and listed in the 2001 report from the Bureau of Labor Statistics. Projected employment in biomedical engineering is expected to increase at a rate 'faster than the average'.

The number of institutions of higher education that have expanded or initiated programs in biomedical engineering has grown significantly as well. The Whitaker Foundation [3] lists ninety university programs offering degrees in bioengineering and biomedical engineering in the United States and Canada, although that number likely has grown to over 100. In 2001, nearly 9,000 undergraduate biomedical engineers were enrolled in our universities (versus approximately 370,000 overall undergraduate engineering students) and 2,700 biomedical engineers were engaged in graduate coursework and research (versus approximately 88,000 total graduate engineering students)[4]. That growth has been fueled in part by the needs projected by the private sector in response to anticipated growth in biotechnology and engineering, in response to the anticipated growth of our aging population and by the influx of monies from private foundations and government agencies that support biomedical science education and research [5].

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[1] The University of North Carolina, Chapel Hill, NC

The expansion of biomedical research programs and education curricula on our college campuses has placed substantial new demands on academic institutions. Program creation and expansion demand new resource allocations for instructional facilities, research support, teaching faculty and ancillary staff. Yet, the economic environment in many public and private institutions is incompatible with those needs as budget shortfalls increase, the cost of new buildings and renovations of existing facilities escalate, competitive faculty and staff salaries rise and the general cost of routine operations increase at rates that exceed inflation. North Carolina, for example will likely have a 2003 state budget shortfall that is expected to be measured in billions rather than millions of dollars and double-digit budget reductions are predicted to befall most state agencies in response to that crisis.

An additional, highly significant challenge to the engineering curricula is the loss of seasoned leadership and the technical and practical experience embodied in those individuals. By 2010, many academic institutions are preparing to lose 33-50% of their experienced faculty as they enter retirement [6]. That loss of talent and experience must be regenerated and expanded to embrace many more professionals dedicated to engineering education. The task of recruiting and retaining dedicated educators is daunting since institutions are placing increasing career demands on new faculty that include the generation of substantial research funding, greater national and international reputations and more refereed journal papers and technical presentations. While engineering faculties overall may see a decline in experienced faculty, bioengineering faculties may be spared somewhat due to its youth. However, recruitment and retention in those programs, especially in the most competitive subspecialties, will continue to be a challenge since the best candidates are likely to gravitate to those programs offering the most attractive start-up packages, including reduced initial teaching loads and abundant TA/RA allocations.

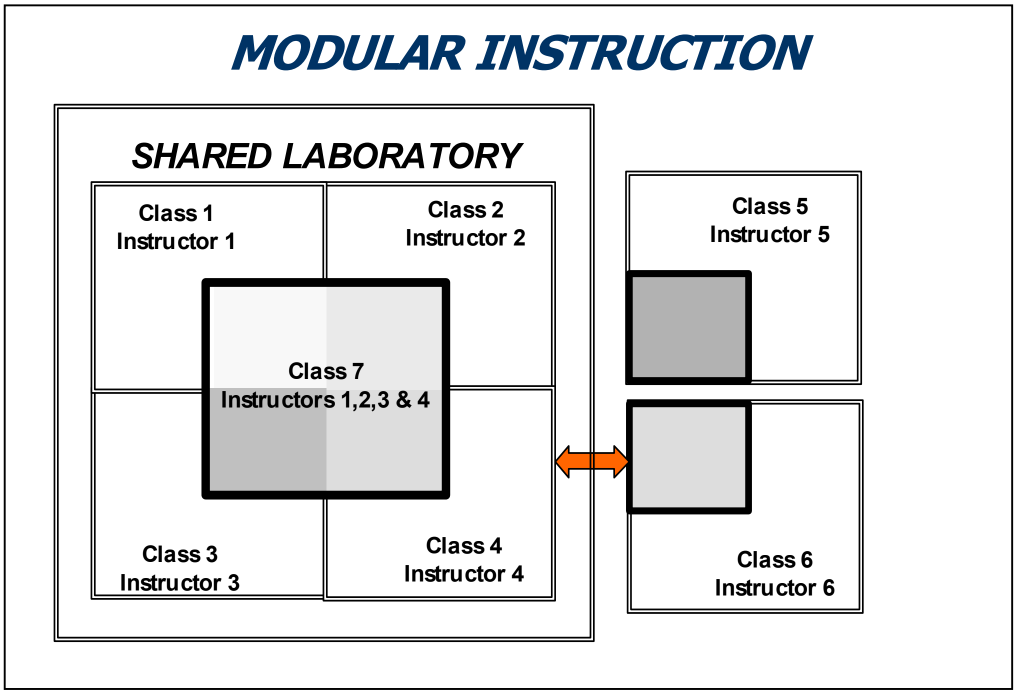
The problems noted above have been recognized, however, and academicians have signaled a slight turn-around. Those actively engaged in bioengineering education see the present as a time of extreme challenge and extraordinary opportunity. Both public and private agencies and nationally recognized foundations have infused academic institutions with tremendous financial resources to improve undergraduate and graduate biomedical training and education. The Whitaker Foundation is expected to award millions of dollars towards biomedical research and education as it concludes its final years ($615M awarded through 2002 [4]). Moreover, the National Institutes of Health, via the newly created National Institute of Biomedical Imaging and Bioengineering (NIBIB), and the National Science Foundation continue to support expanded biomedical science and technology research and education. New graduates in biomedical engineering are assuming both private and public positions at increasing rates and with higher salaries and signing bonuses. Position announcements that specifically seek biomedical engineers are appearing in job postings, in newspapers and at hiring firms.

Objectives

As noted above, the challenge to academic curricula engaged in biomedical research and education is to manage the expansion and enrichment of existing programs in response to the explosive growth of the discipline in a restrictive economic environment. In addressing that challenge, we identified two objectives. ***I. We sought to implement laboratory-based instruction for five identified courses using a single new laboratory configured for those classes.*** Our goal was to expand our curricular offerings to encompass laboratory-based instruction while not compromising our curricular content, overextending our limiting resources or invalidating our programmatic standards. ***II. We sought to exploit that facility so that we might initiate curricular expansion in the setting of group instruction.*** Our goal was to create a newly reorganized laboratory class using a modular, group instruction paradigm that would allow us to readily restructure the content of the course in response to changing student preparedness and need while not expanding or overtaxing our current faculty.

Shared Laboratory Model

Biomedical engineering enjoys a necessary and pervasive draw on mathematics, statistics, physiology, biology, genomics, proteomics, electrical, mechanical and fluid engineering, electronics, chemistry, physics, computer and information technologies, ethics, law, business and commerce, to name a few. Faculty and staff



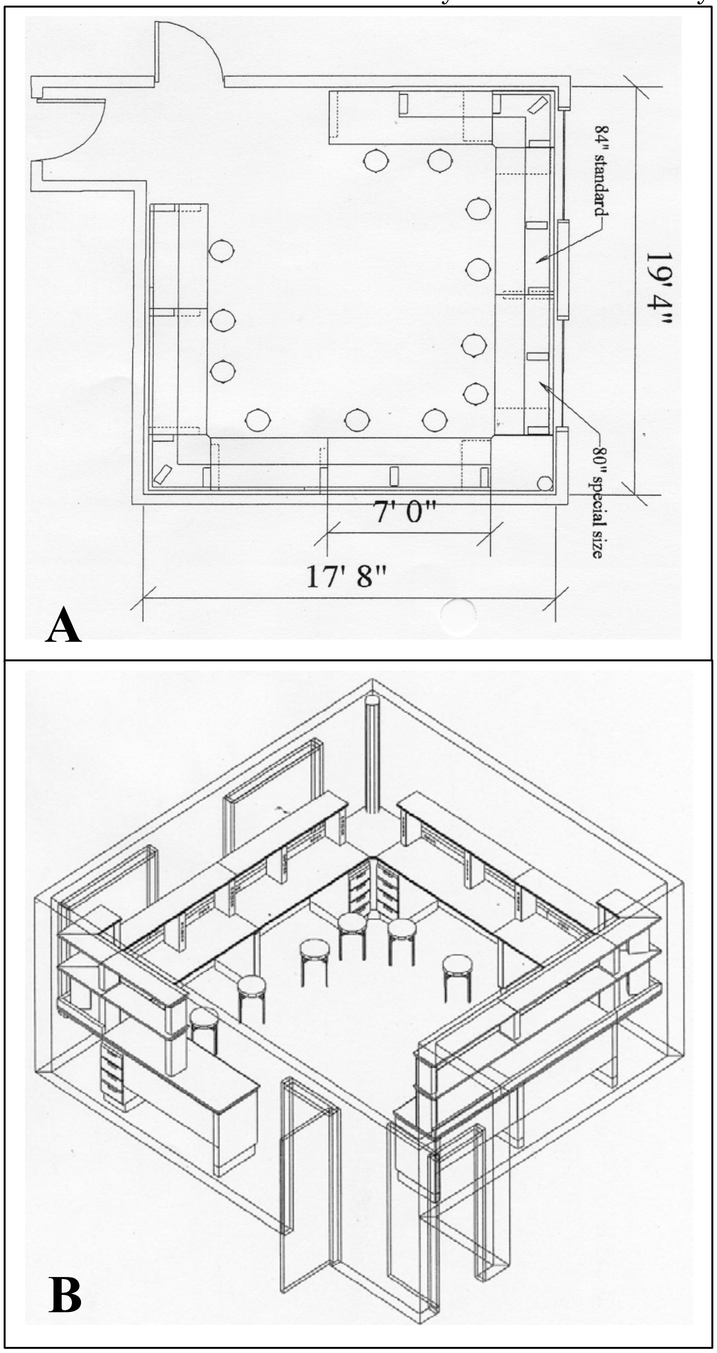
Schematic of the model used for modular instruction in shared laboratory space. The large squares represent an individual instructor and class, shaded portions within a square represent instructional components available for group instruction from a particular instructor. The schematic show a group association of Instructors 1-4, while Instructors 5 and 6 are not associated with the group. The association is shown to lead to a new class, Class 7, which is taught by the several instructors. As need arises, the membership for Class 7 of the association may change by the addition or removal of instructional expertise. Other classes may use the shared facilities, but may not be participants in the instructional group.

engaged in biomedical instruction mirror that interdisciplinary content and include professors in most sub-specialties of medicine, computer science, many disciplines of engineering, biology, mathematics, chemistry, physics and materials. *Thus, biomedical engineering is, by its nature, an interdisciplinary course of study and a prime candidate for instructional modalities that capitalize on shared facilities and team-based instruction.*

The concept of the shared laboratory with modular, group instruction is consistent with the diversity of this engineering sub-specialty and is shown at left. There are two separate concepts of the design presented in the diagram: ***shared laboratory space*** and ***modular, group instruction***. In the diagram, six instructors leading six classes are depicted. Shared laboratory space is achieved as ***Instructors 1, 2, 3*** and ***4*** use a common laboratory space. Two additional classes, led by ***Instructors 5*** and ***6***, maintain separate instructional space with alternate laboratory facilities and, therefore, do not use the shared space. The collective combination of new, yet limited, time and effort commitments from ***Instructors 1-4*** (depicted using shading) permit the creation of a new laboratory class (***Class 7***) having group instruction provided by ***Instructors 1-4*** within the shared facility. Laboratory modularity is achieved by permitting ***Class 6***, for example, to join ***Classes 1-3*** in the shared laboratory while ***Class 4*** no elects to no longer use the facility (orange arrows). Not only will the shared laboratory resources accommodate the addition of the new class, but the content of ***Class 7*** and its modular instructional team will have been modified accordingly, provided that ***Instructor 6*** commits to the additional teaching assignment and joins the association. However, a class may use the shared laboratory space, yet not be a member of the group instructional team, since the shared laboratory and group instructional capabilities are independent characteristics of the model. The instructional modularity of the design permits the faculty to assess and respond to varying proficiencies and instructional needs of the students enrolled. Further, instructional modularity is inherently adaptable to faculty reassignments (*i.e.,* pending grant submission obligations, sabbaticals, course load limitations, *etc*.). These features are particularly novel for our curricular design and very attractive options for young faculty, eager to participate in academic instruction, yet still in the initial stages of their career development and unable to assume primary classroom responsibilities.

In practice, we have five classes using the newly renovated laboratory for the current semester. Those classes are: 1) *Analog and Digital Communication* (RLG), 2) *Real-time Computer Applications I* (RLG), 3) *Analysis and Synthesis of Digital Systems* (SRQ), 4) *Linear Control* (TAJ) and 5) *Electronics for Human Movement Science*

(RLG). The laboratory has blocked times for group instruction and presentations for each participating class. The majority of those times are in the afternoons and the laboratory is readily accessible in the mornings, evenings and weekends for individual study and project work. The building has card-access during the evening hours and on weekends to ensure student safety and the laboratory has keyed-entry to provide limited access and security. Classes and individual students have lockable cabinets and drawers to secure projects in various stages of preparation. The newly restructured class that emerged from a new association of faculty was *Advanced Biomedical Instrumentation.* All faculty submitting this report were involved in that effort. The specialized instructional and laboratory requirements for that class (*i.e.*, those above and beyond items considered part of the shared facility) were assembled by the participating faculty who previously taught similar sections in other courses and could easily relocate equipment and resources for the restructured, group instruction class.



Renovation plan for the shared laboratory. Panel A shows the adopted floor plan while Panel B shows the room elevation plan with cabinets, desks and shelving. The room is designed for seven student pairs (14 students).

In developing the model of the shared laboratory with modular, group instruction, we initiated a 'need assessment', both from a curricular perspective as well as from a physical one. We reviewed our planned class offerings, our current and projected enrollment and instructor availability for a three-year period (the previous year, the current year and the year ahead). Knowing what our class offerings and anticipated enrollments would be, we surveyed our available resources, including faculty commitment as well as physical assets. Together, that data allowed us to formulate a basic shared laboratory configuration that would accommodate the identified instructional demand while permitting the greatest versatility.

We determined that seven potential classes were likely to benefit from the shared laboratory (indeed, five were already slated to incorporate laboratory instruction for the current academic year) and that class enrollment would likely average ten students, although peak enrollments might escalate to a maximum of fourteen. While each class presented unique instructional objectives and required some specialized laboratory capabilities, we were successful in identifying a list of significant tools and resources suitable for a shared facility. Using that data, we designed a shared laboratory space as shown at left. Figure A is the floor plan adopted by the instructional team, while Figure B is the elevated drawings of the facility. With minor modifications, the laboratory can accommodate fourteen students working in pairs at each of seven stations.

The core equipment items required for our laboratory renovations are listed below. The budgeted-list only includes items not otherwise available for the 14-station, 7-pair configuration proposed (*i.e.*, we only

Equipment Order	
Oscilloscope	5
Function Generator	2
Power Supply	7
Multimeter	6
Protoboard	5
Protoboard Socket Plates	10
DAC Board	3
Dell PC	5
EPIC Programmer	8
Serial LCD	7
PIC16F877	25
Control Lab System	1
Physio System	1
Equipment Sub-total	**$42,111**

Renovation Order	
Benches w/ Installation	
Wall Cabinets	
Chairs	
Demolition	
Renovation Sub-total	**$31,704**

TOTAL	**$73,815**

Expenditures related to laboratory renovation, furniture and standard equipment. The 14-student space serves five laboratory classes.

A typical paired-student workstation is shown above. Each station contains general-use items that are supplemented as needed with specialized equipment and capabilities.

purchased core equipment for the laboratory facility that were not already on hand). Each station is equipped with a Pentium 4 Dell, flat screen PC, oscilloscope, multimeter, general use power supply, PIC programmers, prototype boards with accessory power, switches, digital logic and LCD status indicators, function generator, National Instruments 16-channel ADC and function generator. Abundant general supplies of ICs, resistors, capacitors, switches, LEDs, motors, wiring, interconnects and the like are housed in organized bins centrally located within the room. Computers are Internet compatible and configured with recent versions of the most widely used computational software (MatLAB, LabVIEW, Windows NT, Microsoft Office, XILINX Foundation, *etc*.). Two special, single-user systems have been installed to accommodate instruction in Control Theory and Instrumentation (Physiology Section). Those two units serve an entire class and are available on a first-come, first-served basis. One faculty member has general operational oversight and a second assists in monitoring daily activities. The computers are incorporated into our general-purpose computational environment and continue to receive routine maintenance and service from our IT management team. The total expenditure for the facility and equipment was less than $75,000. In addition, current classes have benefited from the addition of five teaching assistants, four that participate in the routine laboratory work associated with assigned course work of the classes that use the shared laboratory and one assigned to the group instructional team.

Arguably, our instructional design more closely resembles an instructional group rather than team. While we have definable membership and a sense of shared purpose, we lack a consciousness of membership and unitary action [7]. In the design of the additional class, we sought to induce team teaching as a consequence of shared facilities rather than create team teaching from the top down. We reason that the benefits of team instruction would manifest themselves as inter-relationships between these classes and the particular expertise of the involved faculty developed. Nevertheless, our arrangement offers several advantages over the isolated instructional format commonly used. Foremost among those advantages is the modularity of the generated class. The versatility of the model and its adaptability to changing student enrollment, interests and needs provides an innovative approach to a difficult challenge in curriculum design. Further, the modular approach, while never intended to be the mainstay of our academic instruction, has allowed us to redesign and expand without the addition of new faculty and initiate the participation of young faculty in the academic process at a time when research efforts are placing large career demands on their time and efforts.

A *subtle* benefit of the shared laboratory facility is the increase in instructional time afforded by that shared arrangement. As noted elsewhere, each of the common features and capabilities of the shared laboratory is presented by only one instructor on one occasion. For example, the first instructor to use the digital oscilloscope in a course or laboratory work leads an appropriate introductory exercise to demonstrate its use and functions. Other instructors may then use that same instrumentation in their laboratory instructional work with only minimal introduction. This component is crucial as we proceed toward accreditation by the US Accreditation Board for Engineering and Technology (ABET) for our undergraduate curriculum. In 2001 [8], ABET changed its focus to ensure that graduates of engineering curricula have skills in communication, multidisciplinary teamwork, and lifelong learning skills and awareness of social and ethical considerations germane to the engineering profession in addition to those in mathematics, science and engineering [9]. However, our students participate in a highly structured, compulsory curriculum in order to meet math, science and engineering requirements and they have little room in their course schedules for additional ABET mandates. Increased instructional times, even those measured by the class period, are crucial for us to meet the challenge of accreditation in that regard and our model generates some of those instructional opportunities.

Conclusions

We have successfully implemented a shared laboratory that is used by several different classes simultaneously. Within that space, we cooperatively teach electronics, instrumentation, controls, microcomputer interface and data acquisition, and sensors. In addition, we have redesigned a group instructed course by the faculty using the shared space. This expansion of our curricular offerings did not result in a new faculty hire or the expenditure of scarce departmental resources. In summary, we believe our shared laboratory space and modular instructional design:

- Eliminates unnecessary duplication of effort.
- Increases efficient instructional time for all faculty.
- Maximizes the use of limited departmental resources.
- Improves student and faculty familiarization, proficiency and productivity in the laboratory.
- Fosters group interactions that may potentially lead to true team teaching.
- Provides curricular adaptability through its modular design.
- Reinforces cross-curricular concepts.
- Provides an economical mechanism to expand curricular offerings.
- Serves as a suitable test platform for emerging research projects and collaborations.
- Encourages expanded mentorship of students by faculty.
- Assists in the ABET accreditation process.
- Provides a mechanism for supplemental student experiences without significant resource allocations.

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Timothy A. Johnson, PhD

Timothy A. Johnson holds a BSEd (1972) in education from Illinois State University, a MS (1976) in natural science from Chicago State University and a PhD (1983) in BME from UNC-Chapel Hill. Research interests include cardiovascular electrophysiology, sensors, instrumentation and data acquisition, processing and display. As an Associate Professor in Biomedical Engineering, he teaches linear controls and directs BME laboratory rotations.

Richard L. Goldberg, PhD

Richard Goldberg, graduate of Bucknell Univ (BS 1988) and Duke (PhD 1994) is currently a research assistant professor at UNC-CH. His research interests are in rehabilitation engineering.

Stephen R. Quint, PhD

Stephen R. Quint received his BS in Electrical Engineering at Virginia Polytechnic Institute in 1970 and PhD in Biomedical Engineering in 1977. He is currently an Associate Professor in the Departments of Biomedical Engineering and Neurology, and Associate Chair of Applied Sciences at UNC Chapel Hill. His research is concentrated in the application of Signal Processing to problems in medicine.

Charles C. Finley, PhD

Charles C. Finley, graduate of Ga. Tech (BSEE-Coop 1972) and UNC-CH (PhD 1983) is currently an Associate Research Professor at UNC-CH in Otolaryngology and Biomedical Engineering. His research focuses on cochlear prosthesis design and application by integrating the techniques of intra cochlear evoked potentials, finite-element modeling and high-resolution CT to explore the basis for widely variable performance outcome across individual patients.

Henry S. Hsiao, PhD

Henry Hsiao, a graduate of MIT (BS 1965, MS 1967) and UC-Berkeley (PhD 1972), is currently a Professor at UNC-CH. His research interests are in microcomputer interfaces and interactive teaching methodologies (remote learning, electronic audience voting, and live internet polling).

Stephen B. Knisley, PhD

Stephen B. Knisley, graduate of Duke University (BSE 1973) and The University of North Carolina at Chapel Hill (PhD 1988) is currently an Associate Professor of Biomedical Engineering. His research interests are cardiac optical mapping and electrical stimulation.