draft Roadmap initiative

Investment in Basic and Applied Science and Engineering

SUMMARY

Initial Charge

The University of Miami's achievements and excellence in the basic sciences, applied sciences, and engineering will be advanced through this initiative. It will cultivate opportunities for multidisciplinary scientific research, teaching, and innovation to ensure the University's capacity to address urgent contemporary issues and problems.

Proposals

- The University of Miami should invest in science and engineering with a focus on problem-based academic clusters in basic science, applied science, and engineering.
- The institutional structures for teaching and research in science and engineering at the University of Miami should be carefully reviewed to maximize quality, impact and innovation.
- The University of Miami should build a complex designed to foster connections among basic science, applied science and engineering.
- The University of Miami should undertake an external review of this proposal.

Investment in Basic and Applied Science and Engineering

Introduction

The University of Miami (UM) has the potential to be a world leader for excellence and innovation in basic and applied science, and engineering research and education. By strengthening individual disciplines in basic and applied science and engineering and promoting interdisciplinary research and education, our faculty will create and disseminate knowledge to improve global society for developed and developing communities. Our graduates will possess not only technical knowledge and excellence, but also skills for leadership and global citizenship.

Guiding principles we considered for this initiative include:

- Leverage existing areas of strength, fill critical gaps, and select areas where we can be first class.
- Focus on no more than five emerging areas of basic science, applied science and engineering.
- Ground the work in basic science, applied science and engineering problems.
- Identify opportunities that lend themselves to world-class multi-disciplinary work not explicitly tied to a discipline; enhance intersections among disciplines.
- Activities will act in synergy with departments.

Problem-based academic clusters

University of Miami's work in basic science, applied science, and engineering should be grounded in problems facing our society and organized in interdisciplinary academic clusters. The resulting scholarly contributions should be relevant to society and support research spanning basic science to applied technology. The University should leverage existing expertise and collaborative opportunities with the Miller School of Medicine (MSOM) and the Rosenstiel School of Marine and Atmospheric Science (RSMAS) as well as other colleges and schools including the social sciences and humanities.

Students will benefit from problem-based learning by experiencing how multiple disciplines approach a problem. Through this work students will be better prepared to work with individuals from other disciplines and will develop deeper critical thinking and collaborative skills – all valued capacities in the modern workplace.

The problem-based academic clusters, which will number 3-5 at any one time, will:

- have a foundation in the basic sciences and engineering;
- have relevance to specific, serious problems facing our society;
- build on existing strengths;
- draw on several disciplines;
- attract investment, external funding, and partnerships; and
- have potential for innovation and relevance.

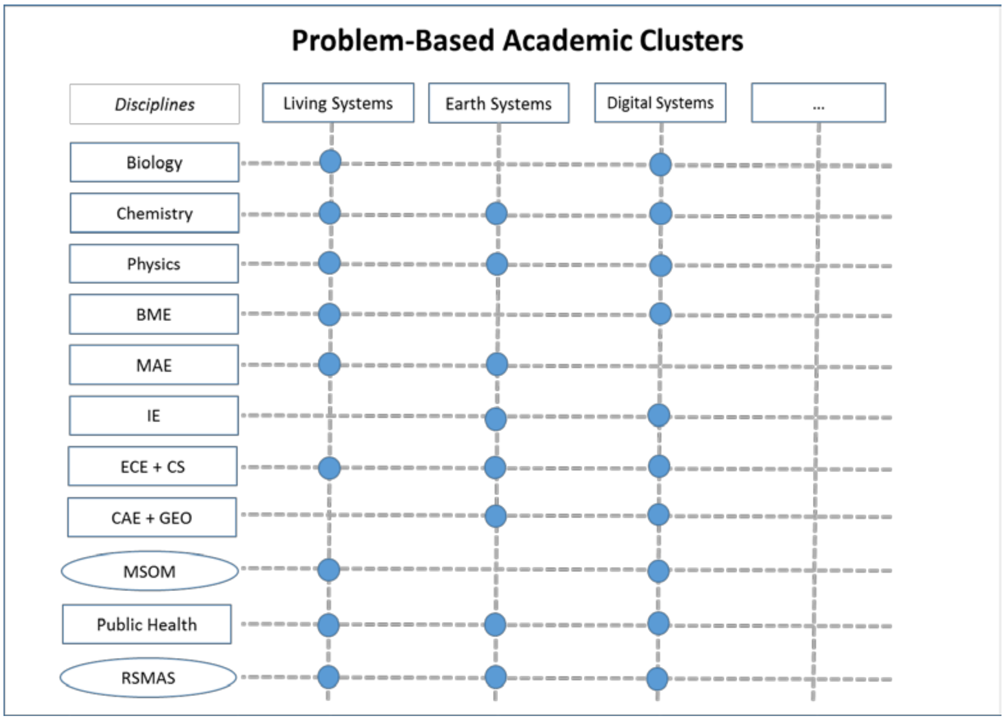
These principles underlie three proposed academic clusters and potential areas of related research:

- Living Systems: Biomaterials and Tissue Engineering, Chemical and Structural Biology, Basic Brain Sciences
- Earth Systems: Sea Level Rise, Urban and Ecosystem Resilience, Environmental Health Risks
- Digital Systems: Health Informatics, Smart Cities, Complex Systems

Investment in Basic and Applied Science and Engineering

Each academic cluster will be championed by a renowned leader, have its own funding, and work closely with the intersecting disciplines. For example, an earth systems academic cluster will draw upon areas of environmental engineering, chemistry, ecology, and geological sciences among others. The academic cluster could, guided by the principles above, address the global challenges of sea-level rise or access to fresh drinking water, building on existing strengths in RSMAS, the sciences, and engineering.

The diagram below suggests how problem-based academic clusters might draw upon a range of disciplines and programs at the University. More intersections may appear as new challenges arise.



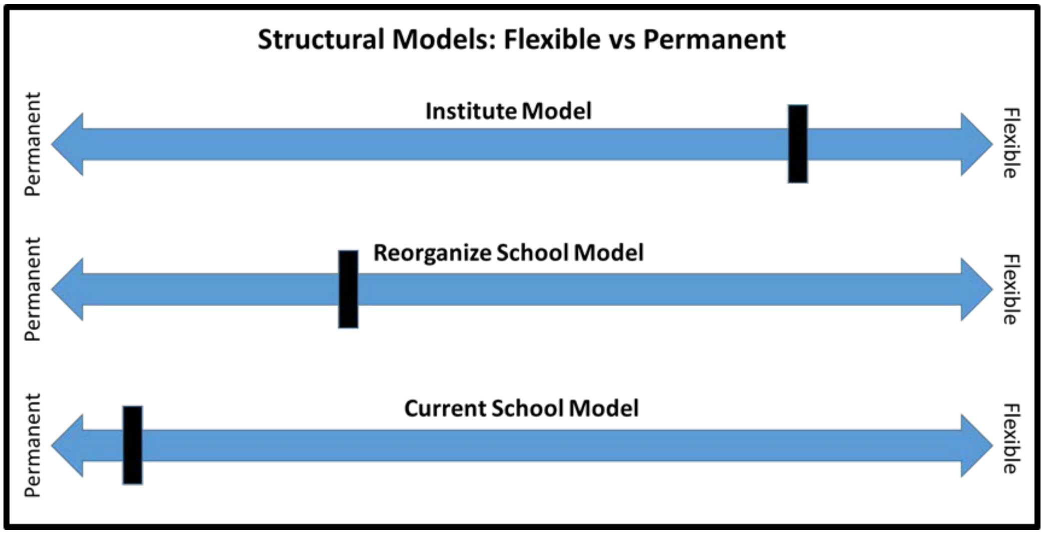
By structuring learning opportunities to address real world problems, the University of Miami can elevate its reputation as an institution invested in the pursuit of solutions and real change. This will allow our faculty to interact in new ways and develop new intellectual approaches. Focusing on problems cutting across disciplines will also impact faculty recruitment by encouraging departments to look beyond disciplinary requirements. A greater emphasis on collaborative, multidisciplinary faculty also presents an opportunity to enhance and diversify funding sources for the sciences and engineering.

The University of Miami should invest in science and engineering with a focus on problem-based academic clusters in basic science, applied science, and engineering.

Structure: Flexible vs. permanent

An increased focus on problem-based, interdisciplinary methods to teaching, learning and research can take root as a pedagogical and methodological approach in a variety of institutional structures. The structures used to encourage integration across the sciences and engineering should be given careful consideration to maximize both the ease with which collaboration is fostered and the potential for innovation to occur. One approach could be to create a center or institute that offers faculty from a variety of schools and colleges a secondary appointment. While providing flexibility, such a structure may suffer from continued transitions and lack of dedicated leadership. Another avenue could be to create a college or school that would provide permanent, shared homes for science and engineering.

Many universities have explored different arrangements and innovative organizational structures. For example, some institutions have separated a College of Arts and Sciences into two distinct colleges: a College of Arts and Humanities and a College of Sciences. Other institutions, have merged the sciences and engineering into a combined College of Science and Engineering. However, an organizational structure that closely links basic science, applied science, and engineering must also understand the importance of social sciences and the humanities. We should carefully review the current organizational structure to maximize the sciences, engineering, the social sciences and humanities.



Institute Model: Create a university-wide institute housing problem-based academic clusters in science and engineering that draws on the resources of existing departments, schools and colleges.

- *Advantages*: The institute can draw upon faculty from a variety of schools and colleges. This flexibility would offer a nimble approach to the problems the institute would take on, and position the institute as a leading convener for intellectual thought.
- *Challenges*: With a flexible set of personnel, the institute may be vulnerable to changes in leadership or other external factors. Faculty may not have a sense of allegiance to the institute since their primary appointment would be elsewhere. Joint appointments can be onerous for junior faculty and can present challenges for tenure decisions. A single new entity provides flexibility but potentially at the cost of trying to take on a scope too broad and with limited institutional security.

Reorganize School Model: Consider different structures of aligning basic science, applied science, and engineering disciplines with small thematic institutes of academic clusters.

- *Advantages*: The smaller thematic institutes allow for flexibility to focus on problems. Opportunity to reorganize and realign departments between the College of Arts and Sciences and College of Engineering. Opportunity to consider alternate structures such as a senior leader to oversee science and engineering efforts.

Investment in Basic and Applied Science and Engineering

- *Challenges*: Science and engineering departments may face challenges integrating due to realignment. A new senior leader function adds another management layer that could complicate the effort to link science and engineering.

Current School Model: Maintain the existing structure of a College of Arts and Science and a College of Engineering with problem-based academic clusters working across the colleges.

- *Advantages*: The academic clusters allow flexibility to focus on problems and would encourage work across the social sciences and humanities in specific, problem-based research.
- *Challenges*: College of Arts and Sciences and College of Engineering faculty have potential for split leadership and conflicting priorities.

The institutional structures for teaching and research in science and engineering at the University of Miami should be carefully reviewed to maximize quality, impact and innovation.

Physical plant

The University of Miami should build a complex designed to foster connections among basic science, applied science and engineering. New buildings could be added to the existing Cox (Biology, Chemistry, Neuroscience, and Geology), Knight (Physics), McArthur (Engineering) and Ungar (Math and Computer Science) facilities. The first building will serve as the integration and "ideation" space with modular lab and maker spaces. This innovative building will foster collaboration among scientists and engineers from different departments and serve as the anchor for this new complex. Faculty offices will be grouped around problems rather than departments or disciplines. The building will have flexible and modifiable research space, multidisciplinary classrooms, and maker spaces.

The design for buildings in the complex should foster not only collaborative research but also the integration of teaching and research through modern teaching environments and gathering spaces for faculty and students. The complex will provide an opportunity to strengthen UM's instructional labs which lack in comparison to peer institutions. A UM undergraduate education in the sciences should be grounded in practice, experimentation and research. Our facilities and faculty should be organized to support this goal.

For example, one floor may have research labs for physics, chemistry, mathematics, environmental engineering, materials engineering, and environmental science focused on an earth systems cluster. Another floor may have research space and faculty from biology, cell biology, chemistry, biomedical engineering and biochemistry focused on a living systems cluster.

It is critical to move forward on this first building as it plays a significant role in beginning the transformation of the sciences and engineering, going beyond the limitations of existing spaces and creating resources, such as modern research and teaching laboratories that UM currently lacks.

The University of Miami should build a complex designed to foster connections among basic science, applied science and engineering.

Investment in Basic and Applied Science and Engineering

External review and interim planning

An external review of the proposals in this paper by prominent science and engineering leaders would advance this initiative by providing additional ideas and existing examples as well as by offering third party expertise and validation. Additionally, retaining a senior individual with a national recognition in science and engineering to assist with the planning, coordination, and execution of this work will accelerate this ambitious initiative.

The University of Miami should take the initial steps to undertake an external review of this proposal.

Criteria for success

For a stronger collaborative and problem-based approach to teaching, learning and research in science and engineering to be in place at the University of Miami by the institution's centennial 2025, the University should:

- Increase the number of National Academy faculty in science and engineering from 4 to 8.
- Double the number of cited publications by faculty in science and engineering.
- Increase the number of competitive, multidisciplinary grant proposals that reflect collaboration.
- Triple the amount and diversity of grant funding awarded to science and engineering faculty.
- Build a thriving science and engineering complex utilizing mixed use space.
- Develop a reputation for world class, relevant research advanced through problem-based academic clusters.
- At least 2-3 disciplines in basic science, applied science and engineering will be nationally ranked in the top quartile.

Submitted for consideration by:

Quad Members: Glen Barber, Amy Clement, Angel Kaifer, Tony Nanni, Claes Wahlestedt
Special Projects Office: Khaleel Seecharan

Appendix A: Clusters and Research Areas

1. Living Systems Cluster

1.1 Biomaterials and Tissue Engineering
Design, synthesis and characterization of novel biocompatible materials for biomedical applications. Combine biological, chemical and materials methods with suitable biochemical and physicochemical factors to improve or replace biological functions. Use appropriate scaffolds to regenerate tissues or to create artificial cell systems and organs.

1.2 Chemical and Structural Biology
Spanning Biology, Chemistry and Physics, Biomedical Engineering and Nanotechnology, it applies techniques, tools and methods and often compounds prepared using synthetic chemistry to study and manipulate biological systems. Chemical biologists not only investigate natural biological systems, but they can also design and develop novel systems with new functions. In addition to basic science, deliverables include novel therapeutics and improved modes to deliver these to living organisms.

1.3 Basic Brain Sciences
Can the human brain understand itself? This is the key question in the exciting area of contemporary neuroscience. Solving the mysteries represented by the normal functions of the human brain as well as its many poorly understood diseases brings together many scientists, from psychologists to physicists, and engineers, and takes advantage of a wide variety of tools to investigate the structure, organization and inner workings of our most complex organ. Moreover, the exciting possibility of machine-brain interfaces is becoming closer to reality.

2. Earth Systems Cluster

2.1 Sea Level Rise

One of the most important problems facing humankind in the 21st Century. It requires research from many different fields, from architecture to science and engineering. In the US, Miami is considered to be ground zero facing this problem and UM must be at the forefront looking for solutions.

2.2 Urban and Ecosystem Resilience

Resiliency is a planning and managing priority to improve human wellbeing in urban contexts based on technical and infrastructural decisions that recognize and address socio-ecological implications. It is intended to avoid energetically-, resource-, and economically- unsustainable long-term maintenance costs.

2.3 Environmental health risks

Health risks related to the environment require interdisciplinary research work from diverse fields of science and engineering. Among these risks are: air quality, water quality and availability, food security, infectious diseases, all of which are widely considered to become extremely important problems facing humankind in the near future.

Appendix A: Clusters and Research Areas

3. Digital Systems Cluster

3.1 Health Informatics

A multidisciplinary field that uses technology to improve health care by combining higher quality, higher efficiency and new opportunities. It is also connected to the field of bioinformatics as genomic and other "omic" information become more readily accessible and cheaper to acquire.

3.2 Smart Cities

Takes advantage of information and communications technologies with the goal of improving the quality of life in urban environments. It requires extensive use of sensors and real-time monitoring devices to manage the city's assets, such as transportation and power systems, hospitals, schools, law enforcement, waste management and other services.

3.3 Complex Systems

The proliferation of very large data sets is one of the facts of modern life. Complexity science investigates how relationships between parts give rise to the collective behaviors of a system and how the system interacts and forms relationships with its environment. Completely interdisciplinary in nature, it requires collaborations among computer scientists, mathematicians, physicists, biologists, industrial and system engineers computer engineers, etc. - often working on social science or economic problems.