NANOSCIENCE & MICROSYSTEMS ENGINEERING

The University of New Mexico

Academic Program Review Self-Study Report

NanoScience and MicroSystems Engineering (NSME)

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Criterion 1. Introductory Section & Background Information

1A: Summary:

Nanotechnology is the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications.[1] Over the last couple of decades, nanotechnology has made a far-reaching impact on our society, including human health, structural materials, environmental sustainability, electronics, and next-generation infrastructure.[2] It is recognized that nanotechnology is central to the development of new manufacturing technologies in many sectors, such as electronics, communication, medicine, energy, as well as consumer products. Microsystems include the study of functional materials and manufacturing methods using microfabrication techniques to create small scale devices including microelectromechanical systems (MEMS) and semiconductor electronics. Nanotechnology and Microsystems often go together as nanotechnology can be used to create new materials or modify materials in order to develop new microsystem devices. While the U.S. has made a significant investment in fundamental nanoscience and infrastructure building, nanomanufacturing, commercialization, and human infrastructure building continue to be a challenge.[3] The nation faces major challenges in revitalization of the manufacturing sector, which is one of the key economic drivers in the U.S. economy, especially with the new Chips Acts which aims to bring Microsystem manufacturing back to the US, and currently there are >40,000 jobs needed to fulfill this demand. Manufacturing contributes disproportionately to U.S. innovation.[4] Proximity to the manufacturing process creates innovation spillovers across firms and industries, leading to the ideas and capabilities that support the next generation of products and processes. In this way, a vibrant manufacturing sector is inextricably linked to our capacity as a nation to innovate.[5] A critical step in building our capacity to innovate is securing our talent pool.

Recent reports have stressed the need to revitalize education in the science and engineering fields so as to attract more U.S. students to these fields and prepare them to compete in the global economy.[5] Education is traditionally based in academic disciplines that require in-Department knowledge in specific areas. While specialization at the Ph.D. level has created immense technological advances, there is a concern that narrow specialization could become an impediment in the increasingly competitive global technology marketplace.[6] The need to meld discovery, innovation and entrepreneurship presents a challenge to educators to provide students with the broader context while retaining technical prowess.[6] Nanotechnology and Microsystems materials and devices requires multidisciplinary knowledge reaching across all STEM disciplines including Sciences (Physics, Chemistry, Biology), Math, and Engineering. With this goal in mind, the faculty at the University of New Mexico embarked in 2004 to create a new interdisciplinary program in Nanoscience and Microsystems (NSMS), which has since changed its name to the Nanoscience and Microsystems Engineering (NSME) program. The NSME program, is an interdisciplinary graduate degree program, that is based on the premise that *the unique properties of*

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[1] M.C. Roco, R.S. Williams, and P. Alivisatos, "Nanotechnology Research Directions: Vision for the Next Decade," IWGN Workshop Report (National Science and Technology Council, Washington, DC 1999).
[2] https://www.nsf.gov/crssprgm/nano/ "NSF National Nanotechnology Initiative (NNI)," (2020).
[3] The National Academies of Sciences, Engineering, and Medicine, "Triennial Review of the National Nanotechnology Initiative," (The National Academies Press, Washington, DC 2016).
[4] Report To The President On Capturing Domestic Competitive Advantage In Advanced Manufacturing, July 2012, http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_amp_steering_committee_report_final_july_17_2012.pdf
[5] Friedman, Thomas L., The World is Flat: A Brief History of the Twenty-first Century. New York: Farrar, Straus, and Giroux, 2006
[6] Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, National Academy of Science, National Academy of Engineering, Institute of Medicine. Rising Above the Gathering Storm. New York: National Academic Press, 2007.

nanoscale materials must be integrated into micro and macro scale systems to be transformed into devices that benefit society. Transforming nanoscale science into systems is our unifying theme, as reflected throughout the academic and research activities, which build upon our capabilities in materials synthesis, interrogative platforms and functional systems.

The self-study report consists of nine criteria. The self-study report will walk the reader through the history and organization of the program along with our mission and vision for the future in Criterion 1. Criterion 2 will provide information on the current curriculum and method of delivering the knowledge and skills to our students. Criterion 3 will provide information on teaching and learning assessment protocols. Criterion 4 will focus on student recruitment, admission, and demographics of our students as well as enrollment over the years. Criterion 5 will focus on the faculty that are involved in the program and professional development services. Criterion 6 will focus on research, scholarship, and services related to the program. Criterion 7 will provide peer comparison. Criterion 8 will provide information on budget and staff, and criterion 9 will provide information on facilities.

1B: History:

Nanoscience research originated on our campus with the establishment of the Center for High Technology Materials (CHTM) in 1983, which arose from an initiative of the State of New Mexico aimed at creating centers of research excellence. CHTM is focused extensively on optoelectronics, semiconducting materials, and multifunctional thin films. The Center for Microengineered Materials (CMEM) was established as the Center for Microengineered Ceramics in 1989 as an NSF/Industry University Cooperative Research Center, and continued to operate an industry-university partnership program for over 20 years. CMEM now serves as the focal point for nanomaterials research and education and, jointly with the Earth and Planetary Sciences Department helps manage some of the major instrumentation for materials characterization. The two materials research centers (CHTM and CMEM) are strategic research centers that report to the Vice President for Research. Together, they helped bring together faculty and research facilities that led to an impressive growth in materials research at UNM. The scientific impact of this research was gradually being recognized and one measure was the inclusion of UNM in the list of High-Impact U.S. Universities. UNM ranked within the top 5 institutions, ranked by average citations per paper, among the top 100 federally funded U.S. universities that published at least 100 papers in ISI-indexed journals of materials science between 1996 and 2000.[7] However, UNM lacked a material science program and we could not attract students who came with undergraduate degrees in materials science and engineering or from ceramics engineering. A UNM faculty member cannot formally serve as an advisor to a student majoring in another department, unless the faculty member has a secondary appointment in that department. This made it difficult to recruit students from other disciplines, which was an impediment since faculty research was increasingly becoming interdisciplinary. Faculty in the sciences and engineering felt there was a need to create a graduate program that would integrate research and education, and provide the educational backgrounds needed for students to effectively participate in the growing technology marketplace. Submission of an NSF/IGERT grant in 2004 allowed these two research centers to expand their ties to the departments outside of engineering, with connections to chemistry, physics, biology as well as the biomedical sciences graduate program in the school of medicine.

The NSF Interdisciplinary Graduate Education and Research Traineeship (IGERT) program in Nanoscience and Microsystems was awarded in the fall of 2005. The NSMS IGERT was one of five that year which received co-funding from the National Cancer Institute Alliance for Nanotechnology. This

[7] ISI Science Citation Index, ranking of High Impact U.S. universities in Materials Science http://www.in-cites.com/research/2001/august_27_2001-2.html

NCI co-funding did not otherwise distinguish our IGERT grant from others, since it did not impose any new reporting requirements. However, the co-funding helped establish a partnership with the UNM Cancer Center and led to the inclusion of Prof. Janet Oliver on our NSMS management team. The partnership that began with the IGERT grant continued to strengthen and led to the NCI R25 Cancer Nanotechnology Training Center (CNTC) grant that was awarded in 2010.

At the outset of the IGERT grant, the establishment of a graduate degree Program was envisioned as a long-term goal. Prof. Abhaya Datye, who served as the IGERT education director was asked to lead the effort to put together the graduate program and to seek approvals from university departments and the administration. These efforts were aided by the active support and encouragement by the Deans of Engineering (Joe Cecchi) and Arts and Sciences (Reed Dasenbrock) who provided staff assistance to develop the degree program proposal. Specifically, Kevin Malloy who served then as Associate Dean for Research in the School of Engineering, and his counterpart Michael Dougher in the College of Arts and Sciences, helped us in facilitating the internal review process for establishment of the new degree. The active interest of the Deans and the faculty helped us seek timely approvals at all levels, and the NSMS graduate degree program was approved by the New Mexico legislature in January 2007. The original structure of the NSMS program involved an Executive Committee to provide oversight for the program, which included the Vice President for Research, and the Deans of Graduate Studies, Engineering and Arts and Sciences.

In the fall of 2007 NSMS began admitting students into the program. The students who had joined the IGERT between 2005 and 2007 had a choice of changing majors or continuing with their original major. Only two students opted to change their major that year. For the rest of the students in the IGERT, and for those students from other departments interested in the educational program, we introduced a NSMS minor in 2008. This was the first Ph.D. level transcripted minor in the School of Engineering at UNM. Other curricular innovations added after the start of the NSMS program include a computational thrust including two courses, one on Density Functional Theory (D.F.T.) course and the other more broadly on modeling of materials. A new computer called NANO was installed with partial funding from the IGERT. The NSMS program helped Susan Atlas with her MRI proposal to get another computer cluster, and most recently the successor to NANO called GIBBS was installed in the computing center. The NSMS team added a Dual Beam Quanta 3D FIB and FEG SEM and a suite of new XRD instruments, all coming from NSF MRI grants. Finally, based on strong student interest, we requested that Engineering be added to our degree program title because we felt that the term Microsystems did not fully capture the engineering aspects of the program. In 2013 the program decided to retain the acronym NSMS but the degrees would be called Nanoscience and Microsystems Engineering. Since then we have now changed the acronym of the program to NSME (Nanoscience and Microsystems Engineering) to avoid confusion, and we are still in the process of changing course titles to NSME. Now these two acronyms are used interchangeably around UNM.

From the outset, the NSME graduate degree program has been a truly interdisciplinary venture. It was formed as a degree-granting program that spanned ten different academic departments spanning the College of Art and Sciences (Chemistry and Chemical Biology, Physics, Biology, Earth & Planetary Sciences, Mathematics) and the School of Engineering (Chemical and Nuclear Engineering, Electrical, Mechanical and Civil and Construction Engineering as well as Computer Science). No other interdisciplinary program at UNM has such a broad base. As the program evolved, it also attracted students and faculty research mentors from the School of Medicine and the UNM Health Sciences Center, and Pathology, Pharmacy and Biochemistry are now full partners in this venture. As new centers were formed at UNM, they also became partners in this program (The Center for Emerging Energy Technologies and

the Center for Biomedical Engineering). The NSME program also helped CBME create another interdisciplinary graduate program in Biomedical Engineering (BME).

NSME is dedicated to outreach efforts. Initially, outreach began as an extension of the NSMS IGERT NSF grant. NSMS IGERT fellows made classroom visits. They maintained a table at the New Mexico State Fair. Fellows also mentored and judged science fairs. Efforts peaked when fellows taught a short course in ethical conduct course required by the entire student body of the Albuquerque Institute for Mathematics and Science (AIMS). Shortly thereafter NSMS evolved as a degree program. At this point NSMS IGERT and NSMS students joined forces to bring a larger sampling of outreach events. Students began to create more intricate demonstrations. In 2009, NSMS student Patrick Johnson and NSMS IGERT fellow Adam Wise held the first Science Night event at Bandelier Elementary School. This show was something of a "Nanoscience Spectacular". Years later NSMS continued to hold the family science nights averaging 250 students and their families at Bandelier and Bellhaven Elementary Schools. In 2009 Heather Armstrong applied for and was awarded the first NISE Network Nano Day kits. These kits focused outreach events through their inventive illustration of nanoscale phenomena. Prior to COVID NSME students and faculty participated in the annual NSME Nanoday celebrations. In 2010 NSMS paired with the Spaciotemporal Modeling Center in bringing the Art of Systems Biology/Nanodays event at the Art Complex in Santa Fe. The event included talks, art exhibitions, and hands on science demonstrations. This event has been repeated every year since prior to COVID. The outreach events brought significant impact to NSME. In both October of 2010 and again in October of 2011 Heather Armstrong was awarded a grant to attend the Nanoscale Informal Science Education (NISE) Network Annual Network meeting. This changed outreach for NSMS in a very meaningful way. At the first conference Heather met with other NISE Network members from New Mexico, most notably Melanie Laborwit from the National Museum for Nuclear Science and History. Through this partnership NSMS would participate in the NOVA promotion for their "Making Stuff" series. We would also average one outreach event (attended by an average of 7 NSMS Ph.D. students) a month. At the 2011 Annual NISE Network Meeting Heather attended a "Science Pub" seminar. She came back to New Mexico convinced this would be a fantastic concept to bring back to Albuquerque. By August of 2012 it was a reality. The first "Science on Tap" event filled all seats and most standing room. Outreach has been and will continue to be an important civic and community building effort. From 2012 till 2020 the NSME program has had been heavily invested in outreach events, and now that things are slowly going back to normal the admin of NSME plan to continue these outreach events if funding becomes available.

In 2009, Kevin Malloy and Abhaya Datye teamed up with John Wood in Manufacturing Engineering, Sul Kassisieh in the Anderson School of Management and Amy Wohlert, Dean of Graduate Studies, to apply for the newly announced Science Masters program. We proposed a Professional Science Masters (PSM) degree program within NSMS, which was offered as a Plan II (non-thesis) masters degree within NSMS. With the addition of the PSM program we expanded the Executive committee to include the Dean of the Anderson School of Management. The PSM program allowed us to create the first successful partnership that required students enrolled in Science and Engineering majors to take courses offered by the Management school and to participate in the Technology Business Plan competition on a regular basis. Since the development of the PSM the Manufacturing Engineering Program (MEP) was created which offers a MS degree via Mechanical Engineering and Anderson School of Management. The NSME PSM degree is not as popular as our traditional degrees anymore but offers a good alternative to individuals

with a more industrial mindset. We feel the NSME PSM represents an important growth direction for the NSME program, and we would like to extend this program to a Ph.D. degree as currently the NSME PSM and the MEP only offer MS degrees. *We therefore seek the input of the review team to determine whether UNM should invest in the PSM NSME program and if we should expand it to a PhD option, as this could be an attractive degree option given the current Chips Acts and semiconductor manufacturing job shortage in the US.*

Since the NSME program is solely dedicated to MS and PhD students there currently is no undergraduate program, so we do not have any teaching assistantships assigned to NSME. However, this is something that we hope to change as enrollment in our lab-based courses continue to increase. Previously, this was overcome by faculty seeking external funding to help support students. In 2009 Debi Evans and Abhaya Datye applied to the Department of Education for the Graduate Assistance in Areas of National Need (GAANN) fellowship program. The program was awarded in 2009 and allowed U.S. to provide TAs for NSMS core courses and to create a summer teacher program as part of the outreach required of all GAANN fellows. NSMS also received a renewal of the GAANN fellowship program in 2012. *We seek input from the review team to learn about other possible graduate fellowships that we should consider*, and *to learn about mechanisms used on other campuses for the support of graduate students in department that do not have undergraduate degree programs*. As ultimately, we would like to offer financial support to 1st year PhD students and international students to help them in their early years at UNM while they find advisors to support them.

This brief early history shows how the NSME program is truly unique in the breadth of interactions and collaborations created across departments and colleges at UNM. It was the first interdisciplinary program at UNM to include partnerships with three schools (A&S, Engineering and Medicine) with faculty that come from 13 academic departments. Throughout the years the NSME program has had >100 faculty involved in the program by mentoring students, but currently there are 23 faculty who are advising students in the FY22 school year. Most faculty are recurring, meaning they continue to support students in the NSME program because they i) like the interdisciplinary nature of the program, ii) appreciate the high-quality candidates, iii) their ability to mentor students outside of their discipline without seeking a secondary appointment, and iv) they appreciate the highly research-oriented curriculum. The program is managed by a team of faculty (the management team) which oversees the curriculum, qualifying exams, and recruitment. In 2012 the management team revised the operating structure so that NSME now reports to the Deans in Engineering, VPR, Graduate studies and A&S. However, we are currently investigating options that would allow us to report to only one Dean in order to simplify the process. *This is another area where we seek input from the review team, seeking to learn how interdisciplinary programs are managed at other institutions and to seek recommendations for our management structure*. Finally, we note that the NSME program was initiated with funding intended mainly as a cost share to the IGERT grant. The IGERT grant officially ended in 2012, so the program needed regular funding from UNM schools. Currently, up to 2020 we were getting annual funds from SOE, A&S, and VPR, but due to COVID cutbacks SOE has stopped providing financial support. We are still in talks with SOE to obtain funds, but we need to seek a more consistent funding source, and one that gives incentives for increasing enrollment. We would also like to include option of increasing revenue if we increase enrollment to help pay for TA and faculty. Our faculty courses are typically cross-listed as faculty have obligations to teach within their department, which complicates differential tuition and course fee payouts. We also plan on writing future educational grants and support to help overcome these financial barriers. We are therefore at a critical juncture, since both the PSM and NSME program reports to multiple Deans and does not receive funding from some of the Deans. We have had many discussions with the Deans of A&S and Engineering, and everyone agrees that the NSME program has a large impact on our students, but we need to secure a

consistent funding source going forward. *This is another area we seek input from the review team: What should be a reasonable level of funding to sustain a graduate interdisciplinary program like ours?*

1C: Organizational Structure:

University of New Mexico Organization Structure:
The University of New Mexico is governed by a Board of Regents. The Board's power to govern the University includes fiduciary responsibility for the assets and programs of the University, establishment of goals and policies to guide the University and oversight of the functioning of the University. The Board is comprised of members who are appointed by the Governor of New Mexico, with the consent of the Senate, for staggered terms of six years except for the student regent who is appointed for a two-year term. The Governor and the Secretary of Education are designated as ex-officio, non-voting members, and the Presidents of the Faculty Senate, Staff Council, Associated Students of UNM, Graduate and Professional Student Association, Alumni Association, and UNM Foundation are non-voting advisors. The President of the University is appointed by the Regents. As chief executive officer of the institution, the President directs the administration in carrying out University Policy, and he has the authority to assign and reassign administrative duties. The current President of UNM is Garnett Stokes.

The six major divisions of the University are headed, respectively, by the Provost/Executive Vice President for Academic Affairs; the Executive Vice President for Administration; the Vice President for Student Affairs; the Vice President for Institutional Advancement; the Vice President for Research; and the Chancellor for the Health Sciences. The current Provost is James Holloway. The current Vice President for Research is Ellen Fisher.

The Office of Graduate Studies (OGS) is responsible for implementing the policies and procedures governing graduate education at UNM. OGS maintains graduate students' academic records, processes graduate assistantships, approves students' Programs of Studies, and provides final review and approval of students' academic performance prior to graduation. In addition, OGS provides review and the first line of approval of departmental curriculum changes for NSME. OGS does not contain any degree granting programs at present. Julie Coonrod was the Dean of OGS who just stepped down as of Spring 2023. The new interim dean of OGS is Jesse Aleman.

NSME Program Structure:
The overall structure of the NSME program is illustrated in the figure below, and consists of an executive committee (Dean's from SOE, A&S and OGS), who report to the Provost. The NSME program is administered by a Director (Prof. Nathan Jackson (ME) (Aug. 2022)), Associate Director (Prof. Susan Atlas (Chemistry and Physics)), and the Academic Program Coordinator (APC) (Yvone' Nelson). The APC is split 50/50 between NSME and BME Program. The Director and APC share an office space with the BME program and Director for the Center of Biomedical Engineering, but there is only one office between the two directors (NSME and BME). The NSME program also consists of a Management Team which consists of current NSME faculty who are involved in the program by supporting or mentoring an NSME student.

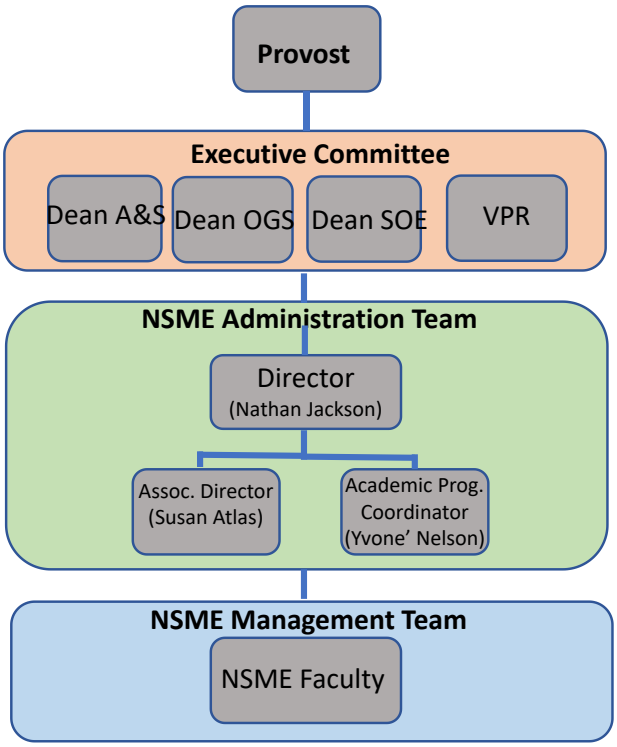


Figure 1. Overall Structure of the NSME Program

Currently, the NSME administration reports to the each of the executive committees, however, recently NSME and the other interdisciplinary programs associated with SOE (OSE (Optical Science Engineering), and BME) have been discussing options to try and simplify the process by only reporting to one Dean. *We would appreciate the review committee's recommendation on the topic.*

NSME is an interdisciplinary program, since it is not a department it currently does not have any dependent faculty members. The faculty members associated with NSME program are assigned to their own departments. This increases our interdisciplinary focus as we currently have 92 members that currently or in the past have supported NSME students. Our faculty have positions in SOE (all departments), A&S (biology, chemistry, physics, and earth and planetary sciences) and Health Science Center (emergency medicine, pharmacy, pathology, molecular genetics, neurology, neurosciences, and orthopedics). However, since members are assigned to their own departments this can affect their NSME duties such as teaching NSME courses and participating in administrative roles such as qualifying exams or MS/PhD committees.

NSME Leadership:

The NSME program has been in operation for 15 years and currently have had three different directors (Prof. Abhaya Datye (CBE) original Director (2007-2014), Prof. Sang Han (CBE) (2014-2022), and current Director Prof. Nathan Jackson (ME) (Aug. 2022). Abhaya is a Distinguished Regents Professor and after his NSME Director position became Chair of the CBE Department. Sang Han stepped down as the Director of NSME in July 2022 to become the new CBE Chair.

The current Director is Prof. Nathan Jackson (ME department SOE) who took over the role and responsibilities of Director of NSME in August 2022. He has been teaching the NSME core class NSMS 519 since he joined UNM in 2017. Nathan has his MS and PhD in Bioengineering from Arizona State University in the area of Microsystems and Neuroscience, as a post-doc he worked at a microelectronics

institute as a material scientist and then later became the Microsystems Group Leader at Tyndall National Institute in Ireland (3rd largest microelectronics institute in Europe). His research experience is very interdisciplinary having graduated Ph.D students in Mechanical Engineering, Biomedical Engineering, Civil Engineering, Electrical Engineering, and Mathematics.

The Associate Director of NSME is Susan Atlas (Chemistry Department and Physics Department A&S), and the APC is (Yvone' Nelson) who took over the position in 2021. All three of the leadership positions in the NSME program are relatively new to the program and are currently working together to learn and improve the program. The Director and Associate Director receive a modest Special Administrative Compensation (SAC) to budget part of their time (~2 weeks per year), but no explicit course release from teaching is provided. Other interdisciplinary programs at UNM pay a larger SAC and increase pay to Director and Associate Director was proposed back in 2012 during the past APR, but nothing came of it, as we would need increased budget. The APC is paid 50% directly through the NSME program's budget and is responsible for the budgets and academic advising and coordination of the program. The remaining 50% of the APC is paid by BME as the position is split 50/50 between the two programs.

The administrative team is responsible for the day-to-day operations of the program including advising students, curriculum issues, funding students/adjunct faculty, recruitment and admissions, program of studies, degrees, and outreach. The management team which consists of faculty who have been involved in NSME in the past or currently assists in curriculum design, teaching courses, suggestions for management, outreach, qualifying exam participation, and recruitment.

1D: Accreditation:

The various schools (SOE and A&S) and the departments within these schools have accreditations such as ABET for SOE. The SOE departments at UNM are undergoing ABET accreditation in FY23. However, the NSME program does not have any specialized external accreditation.

1E: Previous APR:

The NSME programs last APR was conducted in 2012. Overall the review committee was impressed with the leadership and management of the program as well as the unique engagement in the multiple UNM schools. The review committee also had positive statements about the diversity and engagement of our student body and the multidisciplinary curriculum. The committee believed that the NSME research objective of combining nanotechnology and microsystems had significant impact on students and society by providing students with an interdisciplinary education focused on research initiatives. They thought the NSME program did a good job of performing outreach and impacting the local and national community. The committee believed that nanotechnology and microsystems education would have a significant impact on students and society in the long-term as the road-map for nanotechnology and microsystems continues to increase.

Recommendations from the committee in 2012 are summarized below and in **Appendix H**:

1. UNM upper administration should recognize and communicate the added value of interdisciplinary endeavors to its stakeholders.
2. UNM upper administration should provide clear governance policies and an administrative home for the NSMS and other interdisciplinary programs

3. UNM upper administration should provide clear policies regarding resource allocation, credit assignment, workload expectations and faculty evaluations for those involved in interdisciplinary programs
4. UNM upper administration must ensure a more predictable revenue stream to NSMS to support program administration, student recruitment, publicity, seminars, and grant proposal activities.
5. NSMS should build on its strengths to proactively support the economic development initiatives of UNM.
6. UNM should provide a physical home for NSMS.

There have been some efforts to address these problems. For instance NSME has a physical home for the administration office which shares an office with the BME Program. As for the recommendation of allocating predictive funding sources to support the NSME program, the Provost, SOE, and A&S had supplied some funding each year, but over the past 2 years (2021 and 2022) SOE has stopped providing funding and the funding sources change each year, which makes budgeting and planning for the future challenging. However, the challenge is that we rely on funding from different sources, we are currently in talks with the interdisciplinary programs associated with SOE about trying to report to only one source and obtain a steady consistent funding each year from that source.
Question to review committee: If you have any suggestions or recommendations on how to achieve a more consistent budget and reporting process annually, let us know.

Another issue that the NSME interdisciplinary program faces was pointed out by the 2012 review committee is faculty teaching load. Currently, the NSME program does not have any faculty but relies on faculty from multiple schools and departments to teach the courses. However, some department Chairs do not want their faculty to teach NSME courses as they would prefer them to focus on courses within their department. To answer this concern, NSME courses are cross listed with various departments, for instance NSME 519 is cross listed with ME 519 as the instructor that teaches the course is associated with the Mechanical Engineering Department. However, this method also has drawbacks, and some departments still would prefer to have faculty teach core classes within their department. If the university could compensate or encourage departments to have faculty teach courses associated with interdisciplinary programs that would allow us to develop new courses within the NSME program. On the other hand our curriculum allows students to take courses from any STEM based discipline to count for credits towards meeting their degree requirements. However, we have had issues in the past with faculty participating in activities required for the NSME success such as qualifying exams as faculty are typically required to participate in their own departments qualifying exams, and a lot of faculty do not want to participate in both events as they see little benefits. *Let us know if the committee has any recommendations for how we could overcome these issues?*

1F: Vision & Mission:

The overall mission of the NSME is to: Provide graduates with an interdisciplinary education and skill set focused on nanotechnology and microsystems research.

The NSME general educational goals for the program are as follows:

- To prepare diverse, well-rounded, and globally minded graduates with comprehensive understanding of multiple scientific disciplines associated with nanotechnology or microsystems.
- Students will have both a strong core knowledge base and diverse skill set needed to lead the rapidly evolving nanoscale technologies at the interface of traditional disciplines.

- To provide a high level of mentorship and advisement to enable students to graduate in a timely fashion. To achieve this goal, a project management approach is used to guide students through various milestones and involves regular academic advisement by the NSMS office and faculty program directors.
- The Ph.D program curriculum focuses heavily on research as it allows students to take research courses, which gives students more practical hands on experience in nanotechnology and microsystems and allows the students to graduate in a more timely manner.
- To provide an outstanding graduate education built on the foundations of understanding of physical and chemical phenomena at the nano and microscale, and of methods to control and manipulate these materials to make novel structures and devices.
- To develop students who have creative, critical problem-solving skills stemming from team based, multidisciplinary learning allowing them to identify, understand and exploit new phenomena and to transform the knowledge into products and technologies that are useful to society.
- To instill in our students' ethical principles to guide their research and to develop an interest in sharing their knowledge and interests in their communities through outreach efforts.
- To establish strong recruitment efforts to enhance the number of women and underrepresented minorities.

Contributions to UNM Mission:

The mission of the University of New Mexico is to serve as New Mexico's flagship institution of higher learning through demonstrated and growing excellence in teaching, research, patient care, and community service. In UNM's mission statement "UNM's ongoing commitment to these cornerstones of purpose serves to educate and encourage students to develop the values, habits of mind, knowledge, and skills that they need to be enlightened citizens, contribute to the state and national economies, and lead satisfying lives, to discover and disseminate new knowledge and creative endeavors that will enhance the overall wellbeing of society and to actively support social, cultural, and economic development in our communities to enhance the quality of life for all New Mexicans." One of the stated UNM Academic goals is to establish an integrated system of services to prepare, recruit, enroll, develop, retain, and graduate both undergraduate and graduate students at the University of New Mexico, with special focus on the recruitment of high-achieving students.

The NSME program fulfills many of the mission objectives and goals of the UNM administration. The NSME program has served to create a highly collaborative environment across campus that continues to attract outstanding students and faculty from various schools/departments. These students and faculty, through research, publications, externally funded programs and patents have contributed to the research profile of the university. The NSME program has an extremely strong track record of outreach and educational efforts aimed at the New Mexican community.

UNM is in a good position for the continued success of the NSME program. The interdisciplinary NSME graduate degree has been in existence for 15 years. The program has continued to prosper and attract students with a relatively consistent enrollment, although we plan to increase enrollment and attract students from new disciplines in A&S in the future (ie. we just applied for a shared credit program with Department of Chemistry, to attract chemistry undergraduates). Many of the original administrative and bureaucratic barriers to success have been resolved, but as mentioned earlier there are still some that need to be improved focused around budgets and reporting. The NSME program continues to lead the way at UNM to break down barriers between colleges and forge collaborations to enhance the research experience at UNM for both students and faculty.

The contribution made by the NSME program, as an interdisciplinary program, to enhance and expand the UNM mission can be evaluated using a variety of metrics. NSME has been extremely successful in many of these areas:

1. **Fellowships and Graduate Assistantships:** The NSME program has been awarded a number of large training grants in its early years that have been used to recruit and support excellent students in the NSME program. The current management of NSME is interested in continuing to obtain educational grants to help support Graduate student support.
2. **Growth in Enrollment and excellence in retention:** The NSME program grew rapidly during the first five years of its induction and has since been having relatively consistent enrollment with a slight decrease in the past few years, but we have plans to increase this soon. We maintain high retention of UNM students, and we plan to increase enrollment outside of New Mexico, both nationally and globally, where currently 19% of our students are international students. The NSME program continues to have high participation by underrepresented groups in science and engineering (33% female enrollment, 38% underrepresented minority students and 8% Hispanic). The retention rates in the degree programs are also high.
3. **New faculty associated with NSME**: NSME continues to attract new faculty from all Departments to mentor graduate students and serve as mentors and advisors on dissertation committees. Their participation creates a vibrant and evolving research environment. Most faculty are impressed with our curriculum and students and they continue to support students from NSME.
4. **Educational Innovation:** The NSME program continues to evolve as a program. It was the first program to offer a transcripted minor in the Ph.D. and it is the first program at UNM to offer a professional science masters (PSM) degree. The NSME Ph.D. program curriculum is highly focused on research providing students with reduced lecture courses and increased research-oriented courses.
5. **Research Impact and Funding:** Affiliated faculty with the NSMS program bring in large amounts of money ($208,474,302 in past 10 years) in externally funded grants, not all of these have been used to fund NSME students, but we do not have a method of tracking funds associated only with NSME as we are not a department. The funds from NSME faculty are used for research and to help support NSME students through RA's, as we currently do not offer TA positions. The publication track-record of this faculty is excellent.
6. **Curriculum Innovations:** Most of the core courses are offered as online as after COVID we had to alter courses to online versions. NSME 519 is the one exception which has a required lab teaching students on microfabrication skills. However, we are currently investigating methods of providing an online version where students could attend a 1-2 week summer lab. The idea behind this is that we could offer an online degree which would increase global enrollment. *Any recommendations on how to make a lab course online while still providing hands on experience?*
7. **Global UNM Outreach Efforts:** NSME has involved other departments and programs in their very successful outreach efforts. These outreach events have grown to include students from Nuclear Engineering, Chemistry, Biomedical Engineering, Center for High Technology Materials, Civil Engineering, and Electrical and Computer Engineering. Due to COVID the outreach events have reduced, but we plan on rebuilding our outreach events.
8. **Impact on Undergraduate Education:** While the NSME program is a graduate degree program, it has a significant impact on undergraduate education at UNM. A number of nanoscience and microsystems classes have been created at the undergraduate level as a result of the NSME program, including a new Microsystems Concentration for Mechanical Engineering undergraduates (2021). The previous NSME REU program hosted 36 undergraduate students to perform research internships in the summer in the laboratories of NSME faculty. The current NSME management is highly focused on undergraduate research opportunities and aims to make

this an area of focus in the future. Faculty have participated in summer internships through AEOP (DoD) and QU-Reach (quantum REU program).

9. **Research Instrumentation and Facilities:** The NSME program has contributed to several campus-wide research instrumentation projects and has been instrumental in improving and updating computational and materials characterization equipment used by UNM faculty and students.

The program has had significant impact on a global scale as it graduates from the NSME have gone on to have academic, industry and national laboratory careers. UNM in particular is in an ideal geographical location for a nanoscience and microsystems program with SNL, LANL, and AFRL located in the near vicinity of UNM. A large number of students in the NSME program are currently employed at one of these national labs or perform research at the labs through an academic mentor. The NSME program is ideal program for mature students that have been out of academics but working full time, as the program is highly focused on research, where the work experience of the students will benefit them significantly. The interdisciplinary nature of the program promotes work experience as most jobs require interdisciplinary knowledge, therefore students working in industry or national labs find out program attractive for their future careers.

Criterion 2. Teaching & Learning: Curriculum

The M.S. and Ph.D. degree programs in NSME prepare individuals for careers in the emerging fields in Nanotechnology and Microsystems. The NSME program also has a Professional Science Masters (PSM) Concentration, which requires students to take courses in management, however this concentration has gone dormant in recent years. The current Director believes this concentration is important and plans to highlight this option to incoming students in an attempt to increase enrollment. The NSME program is a collaborative effort among several departments in the College of Arts and Sciences and the School of Engineering, as well as the Anderson School of Management, with numerous cross-listed and team-taught courses. The participating departments are Biology, Chemistry, Civil Engineering, Chemical and Biological Engineering, Nuclear Engineering, Computer Science, Earth and Planetary Science, Electrical and Computer Engineering, Mathematics and Statistics, Mechanical Engineering, and Physics and Astronomy. Students who choose the NSME degree program can continue to be advised by, supported by and conduct research with faculty in these departments, and we also welcome other departments to participate in the program. Faculty in the Health Science Center and the UNM Cancer Research center also participate in the NSME program. We have five core classes that every student needs to take, and then numerous elective and seminar courses can be taken from the above listed departments to fit the students specialized research interest.

The PSM Concentration in NSME emphasizes the innovation and entrepreneurial skills necessary to bring discoveries in nanoscience to the marketplace. Candidates for this degree learn the fundamentals of nanoscience, receive hands-on training in microsystems and are introduced to entrepreneurship, innovation and project management. The degree may be completed within one year. This curriculum has been developed in concert with industry and is designed to address present and future professional career needs.

2A: Curricula

The NSME Program Curriculum requires all students to take the five core classes which consist of:

1. **NSMS 510: Chemistry and Physics at the Nanoscale:** This course will introduce students to basic theories and concepts in physics and chemistry that are needed to understand the behavior of matter at the nanoscale.
2. **NSMS 512: Characterization of Nanostructures:** This course aims to give students an understanding of the structure of nanomaterials, physical principles and how they influence material properties, and methods of characterizing materials such as XRD, TEM, SEM etc.…
3. **NSMS 518: Synthesis of Nanostructures:** This course teaches students the principles of how to synthesize nanomaterials using bottom up and top-down approaches.
4. **NSMS 519: Advanced Nano and Microsystems Engineering:** This course teaches students the fundamental theory and hands-on skills related to microfabrication and microsystems. Students are introduced to MEMS and microelectronics and real-world applications and then learn how to manufacture such devices. This is a multidiscipline course which covers topics in, material science, chemistry, physics, solid state physics, mechanics, etc.…. Students learn the theory in lecture form and then learn to apply it by going into a cleanroom where they get hands on skills in basic microfabrication such as photolithography, thin film deposition, etching, doping, and then they get to fabricate a MEMS actuator device (electro-thermal actuator, pressure sensor, electrostatic comb-drive, or lab on chip.)
5. **NSMS 550: Responsible Conduct of Research and Nanotechnology (ethics):** This course teaches students about the ethics of performing research and the professional ethics related to nanotechnology.

A brief syllabus for each core course is illustrated in **Appendix K**. The SLO's for the courses are given in below.

NSMS CORE	Title	Primary Student Learning Objectives	Current Assessment
510	Chemistry and Physics at the Nanoscale	• Students can apply the fundamental laws of physics and chemistry (thermodynamics and quantum mechanics) to explain the behavior of materials on the nanoscale • Students can explain phenomena on the nanoscale in terms of the underlying electronic and molecular level interactions • Students develop skills to read, analyze and understand the fundamental chemistry and physics of a journal article in the field of nanoscience	• Targeted questions on homework and exams • Term project to probe molecular behavior of a nanosystem • Team quizzes on recent literature articles
512	Characterization of Nanostructures	• Students will get an exposure to instrumental methods used for the study of nanomaterials • Students will understand the experimental parameters and factors that affect the data quality and interpretation • Students will use basic knowledge presented in class to formulate an idea that can be tested with the physical tools presented or other techniques not covered in class.	• Problem sets • Exams to test that essential elements are comprehended • Team proposal
518	Synthesis of Nanostructures	• Students understand underlying principles for "bottom-up" assembly of nanostructures • Students learn the techniques for "top-down" synthesis using lithography • Students can use tools the for top-down and bottom-up synthesis to develop a proposal for novel research in the field of nanoscience	• A team project with a written and oral defense mid- and end-of term to develop a new synthetic protocol
519	Advanced Nano and Microsystems Engineering	• Students learn the physical theory of NEMS/MEMS • Students learn the theory and hands on skills on how how to fabricate and characterize NEMS/MEMS devices through lecture and lab. • Students learn the fundamentals of microfabrication for microelectronics and MEMS • Students learn manufacturing techniques for nano and microsystems	• Students undertake weekly microfabrication labs in a cleanroom to get hands on skills on photolithography, doping, thin film deposition, and etching. • Students fabricate and characterize a MEMS actuator device • Students are assessed on theory of microfabrication via exams • A team project (written and oral) on developing a novel MEMS device proposal

550	Responsible Conduct of Research and Nanotechnology (Ethics)	• Students will be trained on their responsibilities and role for conducting research with integrity • Students will learn about established professional norms and ethical principles related to scientific research	Students will attend all classroom sessions and receive a "pass with certification" in the responsible conduct of research

In addition to the five core classes students are required to take other credits depending on the degree as detailed below. The program offers Ph.D and M.S degrees as well as a Ph.D minor for students obtaining a Ph.D in another discipline but want to get a minor in Nanoscience and Microsystems. The five core classes are cross listed with various departments to allow instructors to fulfill their required teaching loads set by their own department. The NSME program has specific technical electives that have NSMS course titles but these are typically hosted by other departments such as NSMS 574L (Microelectronics Processing) which is a course offered as ECE 574, these were cross listed to allow students to search and find relevant courses with ease, but for technical electives students are allowed to take any STEM based graduate level courses. To date the majority 4/5 core classes are dedicated to nanoscience and only 1 microsystem course, students have expressed interest in more microsystem courses. The Director is currently in the process of developing new NSMS microsystem courses and cross listing current Microsystem courses taught in ME (Foundations of Microsystem Design) to the NSMS listing. New courses being proposed include "Microsystem and Microelectronics Packaging" which could be cross listed with Manufacturing Engineering Program as well as a "BioMEMS" course which could be cross listed with BME program.

In addition to the core classes students are required to take:

1. *STEM Technical Elective Courses*: Students are encouraged to take additional TE courses to help them in their research studies for thesis or dissertation students, or courses that interest them for coursework option MS students. However, currently students have the option of bypassing the additional TE courses for more "problems" based courses which allow the students to focus more on their research than on courses. This model is based on the European method where PhD students typically do not take any courses but just focus on their research. However, we encourage students to take courses relevant to their research topic if it will help them in their research. The NSME program is designed to have students learn research skills and to graduate in a timely manner without having to take extra courses that may not help them in their career goals. *The current administration is currently investigating this method and seeing if we should limit the problems-based courses and require more TE or core classes, and we would appreciate any suggestions from the reviewers.*

2. *Seminar:* All MS and Ph.D students are required to take 3 credits/semesters of Seminar. Seminars are meant to increase professional development and to give students an insight into what other academic, industry, or national lab professionals are working on in the area of Nanoscience or Microsystems. The NSME program currently does not have its own seminar series, but we share a seminar with the chemical and biological engineering department and BME program, where NSME invite 4-5 seminar speakers during the semester. Students are also allowed to sign up for other departments seminars such as ME, ECE, Physics, OSE etc… NSME had considered having its own seminar series as then all the speakers would be related to NSME which would increase student interest. However, the cost associated with bringing speakers in from out of state (hotel, flights, and food) as well as cost of providing food and refreshments for students was too high for our budget. If we received an increase in budget this is one area which we would like to provide for our students.

3. *Problems Courses*: "Problem" courses also called "Research hours" from some departments are courses where students get credits and a letter grade to perform a semester long research project with a faculty member. The courses were initially designed to allow students to perform some research work with a faculty member to decide if they were interested in the research topic before they select an advisor for their thesis or Dissertation, or for students that chose the "Project" based M.S degree option. The research topic and evaluation is dependent on the faculty member. Most departments have a limit of 6-9 credits that can be counted towards the students degree requirements. However, the NSME program currently allow students to substitute these courses for TE courses. The current Director has thought about setting a credit limit of around 12 credits, so that it is higher than other departments but lower than current procedure which has no limits. *Any suggestions by the review committee would be appreciated?*

4. *Thesis or Dissertation:* If students are in the coursework option, then students are not required to take these but must sign up for more TE or Problem courses.

Undergraduate Degrees: The NSME program does not have an undergraduate degree option as we are not a department, but we do participate in the SOE "shared-credit program" which allows students to take +500 level courses which would count towards their BS degree requirement as well as their Graduate degree requirement (double dipping). The program is meant to encourage undergraduates to continue on and obtain a graduate degree at UNM. As students can take up to 12 credits as an undergraduate that count towards their graduate degree requirements. Since the MS NSME coursework option degree requires a total of 30 credits, students can take 12 credits as an undergraduate and then only need another 18 credits to get a MS degree, therefore allowing students to get an MS degree in approximately 1 year (9 credits each semester). Undergraduate students need to apply to this program within their own departments to first be accepted into the shared credit program. Students need to have a GPA >3.0 to be admitted into the shared credit program. Students with GPA >3.5 are typically accepted into the program with little paperwork. Students with GPA between 3.0-3.5 need to go through a review process and obtain reference letters. Besides the graduate credit students also have the advantage with easier acceptance into a graduate program.

The shared credit option is relatively new to SOE, and currently is only available to SOE undergraduates. Since the NSME also gets students from other schools we are currently trying to get the shared credit program into A&S departments. The NSME administration have submitted a request to UNM upper admin to get a shared credit program between NSME and Chemistry Department to be implemented in Fall 2023. If this is accepted we will use this with various other A&S departments such as Physics and Biology. Chemistry was chosen initially as this is the A&S department where we get the majority of our graduate students.

The degree requirements for the various MS options and PhD are given below:

NSME (M.S.) Requirements
M.S. faculty advisor/mentor
Students are responsible for selecting a faculty mentor who will help them establish a Committee on Studies (COS). The program office will aid students in their selection process. Ideally, students and faculty members will agree about the advising/mentoring relationship but for those who need assistance, the Director and APC will assist the student. We encourage faculty to review the degree requirements as they could be different than their primary department, but the APC is there to assist faculty and students in determining their course studies.

M.S. committee on studies for Thesis option
The student and faculty mentor invite three faculty members to serve on the student's COS. The committee members help the student to plan a Program of Studies (POS)–a list of courses that meets the student's interests and needs which will be counted toward the degree. This plan must be approved by the student's advisor and the NSME Program Director prior to being submitted to the OGS. The Committee also supervises the student's progress and conducts the required thesis or other exams. If the student subsequently qualifies for entering the doctoral program, this committee can continue in the role of Doctoral Studies and Dissertation Committee to assist the student in completing the Ph.D.

M.S. general degree completion requirements
The maximum time-to-degree for Master's students is 7 years, during which time the student must be enrolled full time for at least three consecutive semesters. A student must take 9 credit hours to be a considered a full-time student by financial aid. If the student has an assistantship, full time is considered to be 6 credit hours per semester. To complete the M.S., students must maintain a minimum cumulative grade point average of 3.0 in graduate-level courses taken in graduate status and a GPA of at least 3.0 for courses listed in the POS. Students cannot graduate with incompletes pending nor while on probation.

Three M.S. plans: degree completion requirements
There are three options to receive a M.S. in NSME.

Plan I (Thesis Option)
The student must complete all five core course requirements.
Student must complete a total of 24 credit hours.
Student must complete a minimum of 6 thesis hours.
Students then have to successfully defend their MS research and manuscript to their COS.

MS I

	Semester	Credit Hours
NSMS 510 - Chemistry & Physics at the Nanoscale	Spring	3
NSMS 512 - Characterization Methods for Nanostructures	Fall	3
NSMS 518 - Synthesis of Nanostructures	Fall	3
NSMS 519 - Advanced Micro & Nano Systems Engineering	Spring	4
NSMS 550 - Social & Ethical Implications of Nanotechnology	Fall	1
STEM elective		3
Seminar		3
Problems		4
Thesis		6
TOTAL		**30**

* NOTE: STEM electives can be substituted for Seminar and Problems

For option I thesis, there is a maximum of 6 credits allowed of Problems (NSMS 551) and maximum of 3 credits for Seminar.

Plan II (Project)
Students must complete all core course requirements.
Student must complete 32 credit hours. The NSME admin has thought of increasing the coursework option credit load in an attempt to motivate students to select the thesis option, but we have not made any changes as of yet. The project is typically performed under the advisement of an NSME faculty member in a problems course.

MS II		
	Semester	**Credit Hours**
NSMS 510 - Chemistry & Physics at the Nanoscale	Spring	3
NSMS 512 - Characterization Methods for Nanostructures	Fall	3
NSMS 518 - Synthesis of Nanostructures	Fall	3
NSMS 519 - Advanced Micro & Nano Systems Engineering	Spring	4
NSMS 550 - Social & Ethical Implications of Nanotechnology	Fall	1
STEM elective		9
Seminar		3
Problems		6
TOTAL		**32**

* NOTE: STEM electives can be susbtitiuted for Seminar and Problems

Plan III (Coursework Option)
The coursework option MS degree requires students to take 30 credits including all five core classes and 3 credits of seminar and the remaining credits can be taken from any graduate level STEM course.

Professional Science Masters (PSM) Curriculum
Students must complete all core course requirements and other stipulated courses.
Students must complete 32 credit hours, which includes the NSME core classes (14 credits) as well as the following courses from management (19 credits).

MGMT 514, Technology Entrepreneurship (3)
MGMT 513, Technological Assessment & Forecasting (3)
MGMT 516, Entrepreneurial Finance in High Technology (3)
MGMT 556, Starting New Business (3)
NSMS 595, ST: SMP MI and T Workshop Seminar (2)
NSMS 595, ST: Independent Project (internship) (2)
NSMS 650: Research (3)

NSME Ph.D. degree requirements
Ph.D. faculty advisor/mentor
Newly admitted doctoral students must also go through the process of selecting an advisor/mentor. They will then request the Graduate Subcommittee that the Qualifying Exam be scheduled sometime during or immediately after they have completed all the core courses. The program office will aid students as needed in their selection process.

NSME qualifying examination procedure
General requirements for the Ph.D. degree are set by the Office of Graduate Studies (OGS). Required NSME core courses are described below. Students who wish to Advance to Candidacy in NSME must pass a program qualifying examination. This examination covers the four core subject areas listed in this section and should be taken as soon as possible after entering the program (ideally after 1 year). The qualifying exam is an oral exam that is meant to assess the students ability to critique a research paper, and then develop a research proposal based on the key finding in the paper or research topic:

1. Oral Examination: The Ph.D. qualifying exam consists of an independent, critical analysis of a research article by the student (the student is given a selection of papers to choose from which are outside the students research topic) and the preparation of a research proposal. The student will deliver a 30-45-minute presentation to critique the research paper and present the novel research proposal. The student will be allowed two attempts for qualifying exam. The oral exam is presented

to three faculty members (students advisor is not allowed to participate on the committee). The committee then submits their recommendation to the NSME administration who determine if the student passes or fails.

The NSME qualifying exam direction, rubric, and scoring criteria is available as Appendix J.

Ph.D. committee on doctoral studies

The student and faculty mentor invite three additional faculty members to serve on the student's Dissertation Committee on Studies. The committee members help the student to plan a POS that is reflected on the student's Petition for Candidacy form. These courses meet the student's interests and needs which will be counted toward the degree. The Petition for Candidacy must be approved by the student's advisor and the NSME Program Director prior to being submitted to the OGS. The Dissertation Committee also supervises the student's progress and conducts the required exams.

Ph.D. Candidacy Requirements

To advance to candidacy students must:

1. Satisfactorily complete all NSME course requirements.
2. Pass the qualifying exam.
3. Pass the comprehensive exam
4. File all required paperwork by required time deadlines.

Ph.D. General Degree Completion Requirements

The NSME Ph.D. requires that students complete 48 credit hours of courses plus 18 credit hours of dissertation research credit (699). Overall, the basic requirements for Ph.D. candidates include the five core courses. Additional details are available in the Graduate Program section of the UNM Course Catalog under the heading Doctoral Degree General Requirements. These are minimum requirements. The actual number of thesis or dissertation credits will in most cases be larger.

Students who have already gotten a MS degree prior to their PhD studies are required to take the NSME core classes and a STEM elective along with seminar, problems and dissertation hours.

PhD (Doctoral)		
	Semester	**Credit Hours**
NSMS 510 - Chemistry & Physics at the Nanoscale	Spring	3
NSMS 512 - Characterization Methods for Nanostructures	Fall	3
NSMS 518 - Synthesis of Nanostructures	Fall	3
NSMS 519 - Advanced Micro & Nano Systems Engineering	Spring	4
NSMS 550 - Social & Ethical Implications of Nanotechnology	Fall	1
STEM elective		3
Seminar		3
Problems		6
Dissertation hours		18
TOTAL		**42**

Students who skip the MS and go directly to Ph. D program in NSME will be required to take more STEM elective courses as illustrated below:

PhD (Doctoral)		
	Semester	**Credit Hours**
NSMS 510 - Chemistry & Physics at the Nanoscale	Spring	3
NSMS 512 - Characterization Methods for Nanostructures	Fall	3
NSMS 518 - Synthesis of Nanostructures	Fall	3
NSMS 519 - Advanced Micro & Nano Systems Engineering	Spring	4
NSMS 550 - Social & Ethical Implications of Nanotechnology	Fall	1
STEM elective		22
Seminar		3
Problems		9
Dissertation hours		18
TOTAL		**66**

Overall, the curriculum is meant to encourage students to take more research-oriented credits as this is where students will get the skills and knowledge that they need in their future careers. The NSME administration feel that requiring students to take courses might not be in the best interests of the student. Graduate courses are meant to help assist the student in their research and to provide the student with a diverse level of knowledge which we believe our core classes provide. However, we have had students request more technical elective courses in the Microsystem area and we are currently looking into creating new courses through the ECE, ME, and CBE.

Ph.D. Minor in Nanoscience and Microsystems
Students who satisfactorily complete 3 of the 4 NSME main 3+ credit core courses required by the NSME Ph.D. program (NSME 510, 512, 518, 519) will be awarded a transcripted minor at the Ph.D. level.
Curriculum for Students in the NSMS M.S. & Ph.D. Degree Programs

Currently students in the NSME program are able to obtain concentrations in the following categories, but we plan to add a microsystem category in the near future:

Group 1: Nano-bio Interface: This concentration focuses on biological and chemical reaction, biosensors platform fundamentals and applications through nanofluidics and biomimetics. We have suggested courses TE courses including NSMS 538 (biosensors), NSMS 530 (surface an interfacial phenomena), NSMS 522L Fundamentals of nanofluidics.
Group 2: Complex Functional Materials: This concentration exposes students to specific interface science, materials synthesis, and processing. Suggested TE courses include NSMS 530 (surface and interfacial phenomena), NSMS 533 (vapor and aerosol phase materials processing), NSMS 569 (advanced materials science) and NSMS 575 (polymer science and engineering).
Group 3: Information Nanotechnology: This concentration exposes students to materials growth processes, quantum devices, and nanofabrication techniques. The suggested TE courses include NSMS 532 (nanoscale electronic and photonic devices), NSMS 571 (quantum computation), NSMS 572 (semiconductor physics) NSMS 574L (microelectronics processing), and ME 518 (Foundations of MEMS Design).

2B: Mode of Delivery:

The five core classes are taught face-to-face. During COVID the courses were taught online, and since then four of the courses (all except NSME 519) have offered face-to-face or online option. NSME 519 involves a lecture which could be offered as an online option but the course also includes a lab where students go into the cleanroom and learn how to perform various microfabrication techniques and make a basic MEMS device. The hands-on skills learned in this class are critical skills that help our students obtain jobs. The NSME 519 course in 2021 resulted in nearly half of the students obtaining a job at Intel or SNL (MESA facilities) upon finishing the course, the other students were still pursuing their graduate

degrees. Students and industry partners have given praise to the course and the skills learned by the students.

Ultimately the new Director (Jackson) has expressed an interest to create an accelerated online NSME program that would offer an online MS degree. This would increase our enrollment in the MS program and allow students to get a degree from other parts of the country. Similar programs have had success at UNM in the Aerospace ME/ECE program as well as other universities such as ASU. However, to accomplish this all five of the core classes would need to be available online as well as several technical electives and seminars. The Director and instructor for NSME 519 is currently working on methods of creating a lecture online course and a 1 credit lab course that could be offered in the summer to online students, where students could come to UNM for 1-2 weeks during the summer and complete the labs. The Director has participated in URE ATE programs at UNM following a similar concept. However, one challenge in this approach is paying the faculty or TA during the summer to teach the lab course, but we currently have proposals in to the Provost office to cover the expense. In addition any new courses that fall under specialization of NSME would be encouraged to have an online section to create technical electives to meet the degree requirements. The online MS degree would increase enrollment and budget through higher differential tuition returns, but this means higher burden on instructor's course load, so we need to work with executive committee and provost to overcome these challenges.

Criterion 3. Teaching & Learning: Assessment

3A: Assessment Plans

As part of the SOE, the NSME program completes an annual assessment document used by the SOE. A rubric was created to assess students knowledge and skills as related to the program which is completed by the committee of studies (COS) of the student during their MS Thesis defense and their Ph.D dissertation defense. The Rubric is attached to **Appendix I**. The rubric used was created by first identifying the goals of the MS and Ph.D.

<u>Ph.D Program goals and Student Learning Outcomes (SLO):</u>

1. Demonstrate Knowledge of Nanoscience and Microsystems Fundamentals
2. Ability to conduct original and independent research
3. Ability to critically review literature related to specialized field
4. Ability to communicate effectively
5. Demonstrate a Depth of knowledge of specialized field

MS Program Goals and SLO:

1. Apply their knowledge of Nanoscience and Microsystems fundamentals appropriate for discipline and specialization.
2. Ability to communicate effectively in oral and written form
3. Ability to critically assess or apply information in nanoscience and microsystems.

Students receiving scores of >3 are considered acceptable. The goals and SLO are meant to assess the students' knowledge, skills, and responsibilities in the area of Nanoscience and Microsystems. Assessment is completed at the time of the defense by the COS, so students and the program are assessed as the student completes their degree. However, for the MS program we currently have options I, II, III which are thesis, project, or coursework options. This assessment is only valid for thesis or project (I and II) as these involve a committee and defense of their work. Recently, we have had an increase in students choosing option III

(coursework MS). In the coming year we will change our assessment of MS program to include a GPA assessment for coursework option students, where an acceptable GPA of >3.0 will be used to assess the program. Since all Ph.D students need to defend their work the current assessment plan will continue. *Do the reviewers have any opinion on other methods that could be used to assess coursework option MS students?*

In addition to the end outcome, we also assess the program and students progress during the qualifying exam where a rubric is used by a qualifying exam committee (3 faculty members not associated with the students advisement). The rubric is used to determine if the student has met the requirements determined by the Management team and Administration to continue on in the Ph.D program. This assess the core classes and allows us to determine if students are getting the necessary knowledge in these courses. The rubric for qualifying exam student assessment is provided in **Appendix J**.

3B: Assessment Reports.

The assessment report results for 2021 are provided below for the Ph.D and MS. The results for the Ph.D assessment demonstrate that all 6 students who completed their Ph.D scored higher than 3.0 in all the categories as shown in the table below.

Part III: Assessment REPORT Body
UNM Academic Programs/Unit Combined Assessment Plan and Report Template
The University of New Mexico

SLOs (copy and paste from PLAN above) *Copy and paste your SLOs from your entries in the PLAN above that were **measured during this year**.*	**Student Population** *Describe the sampled population, including the total number of students and classes assessed.*	**Results*** *State whether the performance benchmark was met, not met, or exceeded AND the total number of students assessed (i.e., Exceeded, 95 out of 111 (86%) students)*
Knowledge of Nanoscience and Microsystems Fundamentals	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.2
Ability to conduct original and independent research	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.5
Ability to critically review literature related to specialized field	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.3
Ability to communicate effectively	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.1
Depth of knowledge of specialized field	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.2

The MS program only had 1 student who graduated with option I Thesis defense, but the result of the assessment is provided below:

Part III: Assessment REPORT Body
UNM Academic Programs/Unit Combined Assessment Plan and Report Template
The University of New Mexico

SLOs (copy and paste from PLAN above) *Copy and paste your SLOs from your entries in the PLAN above that were **measured during this year**.*	**Student Population** *Describe the sampled population, including the total number of students and classes assessed.*	**Results*** *State whether the performance benchmark was met, not met, or exceeded AND the total number of students assessed (i.e., Exceeded, 95 out of 111 (86%) students)*
Knowledge of NSME Fundamentals appropriate for discipline and specialization	Graduating MS students with the thesis option for 20-21	4
Ability to communicate effectively in oral and written form	Graduating MS students with the thesis option for 20-21	4
Ability to critically assess or apply information in NSME and specialization	Graduating MS students with the thesis option for 20-21	4

Since the Ph.D students and MS students all scored values greater than the minimum no changes to the program were recommended. However, we had more MS students graduate with the coursework option and as stated above we will start assessing the MS option III program based on GPA.

To ensure high quality education the NSME program goes through a number of assessment, including assessing students during the qualifying exam for Ph.D students to ensure that they understood the core class concepts. In addition each Thesis (Ph.D and M.S) defense is assessed using a rubric to ensure that students displayed a good fundamental understanding of nanoscience and microsystems. A new method that the Director is thinking to implement is to survey recent graduate students after they receive employment to get student feedback on the program and determine if any changes to courses or program are necessary. For instance, in recent survey some students wanted more classes on Microsystems, and we are currently in the process of adding courses in this area as technical electives.

3C: Primary Constituents

There are numerous constituents and stakeholders within the NSME, including students, faculty, administration, employers, New Mexico taxpayers etc… The SLO are provided to the students in the form of the rubric before any examination. All new students participate in a student orientation where the goals of the program and other useful information are provided to the students. In addition, students are encouraged to discuss any issues or clarifications with the Director and APC. After the exams such as qualifying exam students who don't pass are encouraged to talk to the Director about their results and how they can improve or what their options are going forward. The website also has a lot of the information for students, we are currently in the process of updating the website to have the most up to date information. Information and highlights about the program are disseminated to the New Mexico community and related industry via our LinkedIn page and our website that provides news and highlights.

A brief list of employers of our students is provided in more detail in section 4F below. The administration does value feedback from former students and their employers on how the program could be enhanced to fit their needs, but we currently do not seek their feedback. The current Administration would like to include this in the future. To accomplish this we would keep track of our former students and then seek their feedback.

Criterion 4. Students (Undergraduate & Graduate)

4A: Recruitment

Recruitment is critical for the growth and enhancement of the program. The NSME administration throughout the years implemented various methods for recruiting excellent students. The program relies on faculty and students to achieve high quality academic excellence. Most top-tier universities focus on name recognition to attract the excellent students. However, since this is an interdisciplinary program that does not have any US or World ranking and is relatively young (15 years) we require not only word of mouth from past students, but we must actively recruit students to ensure we get top qualify students outside of NM (nationally and globally). UNM is a Hispanic Serving Institution with >50% Hispanic population enrollment. The SOE graduate program has similar demographics, consisting of 65.1% of Ph.D students and 59.3% of M.S students as under-represented population as of 2021, and 27.5% of Ph.D students are females which is much higher than national averages of ~15%. Recruitment consists a) recruiting students (M.S or B.S) from UNM to stay and apply to NSME, b) recruitment in NM from other universities, c) recruit nationally, and d) recruit international students. The priorities of recruitment are in that order, we first want to have high retention from our excellent undergraduate students at UNM to stay

and join our program. Since UNM is a minority institute most of the students we recruit from UNM are under-represented students. In addition, most of our students have a B.S in Chemical or Biological engineering or Chemistry which typically have a higher female concentration compared to other STEM disciplines. Through outreach events the NSME program provides STEM events for local K-12 students. The current administration wants to increase enrollment for under-represented and female students within the program.

Undergraduate Student Recruitment at UNM:

Our top priority is to keep excellent students at UNM and to encourage students from various A&S and SOE disciplines to consider applying for an interdisciplinary degree in NSME. In the past the NSME did this by encouraging advisors to promote the program, however this was a challenge as advisors work for their department and obviously want students to stay within that department. The new administration is going to host a recruitment event to be advertised to all Junior and Senior undergraduates from SOE and A&S where we will have talks from students, information, and of course food and refreshments to let students know about the NSME program and why they might be interested over some of the traditional disciplines. We will highlight job market, quick graduation rates, diversity of faculty to choose from, and interdisciplinary nature of the program. We have also created a flyer which highlights these which we send out electronically to each department (starting Fall 2022). In addition, we are letting students know about the shared credit program, and we are trying to get the shared credit program extended to A&S (where we have applied for the program for Chemistry Department to start Fall 2023). Extending the shared credit program to A&S departments will allow students to take the core NSME courses in their Junior and Senior year up to 12 credits and then students would only need 20 more credits (10 each semester) in order to get their M.S degree in 1 year after their B.S. By taking core NSME courses student will learn about the program and become interested, we also encourage faculty in NSME to participate in undergraduate research opportunities, so students can gain an interest in nanoscience or microsystems. If we had funding to support students to participate in REU that would be an advantage as well.

Social Media Recruitment:

Most students get their information about various universities and graduate programs through word of mouth, conferences, and social medial. As our department matures, we will get more word-of-mouth recognition as our graduated students are getting more executive roles in industry and academia. We always encourage students to attend conferences to disclose their research and highlight on any poster or presentation that they are from UNM and part of the NSME program. In addition the Director takes flyers to conferences he attends and distributes them to try and increase the reputation of the program on a global scale (ie. he distributed flyers at IEEE MEMS 2023 in Munich, which is the largest MEMS international conference). To date the NSME program has had little exposure on social media platforms. Recently the Director created a LinkedIn NSME page, and we hope to fill this in with highlights when students publish papers or present at conferences, as well as post recruitment flyers, and outreach events. Using the administration and management teams networks we can reach more students to let them know of the achievements being made from UNM NSME. In addition we are currently in the process of updating the website which has old information, and we hope to develop a method of maintaining the website, which is critical as this is where students go to get their information.

In the past NSME performed an annual recruitment event where we invited select students to UNM and showed them around and tried to motivate them to apply towards the NSME program. Overall, the new administration hopes to increase recruitment and enrollment using the following:

1. Create Shared Credit Program for A&S departments at UNM

2. Increase recruitment for undergraduates at UNM by hosting annual recruitment events to SOE and A&S
3. Increase Social Media Presence
4. Create You-tube video of past graduate confessions
5. Update Website
6. Increase K-12 outreach events
7. Send flyers about program to UNM as well as other universities (national and globally) through our list of networks
8. Send Flyers about program to local national labs (SNL, AFRL, and LANL)
9. Work with ESS on getting undergraduate research positions from faculty related to NSME.

National Laboratory Recruitment:

In the past a significant number of our students were employed at one of the three national laboratories in NM (Sandia National Laboratory, Air Force Research Labs, and Los Alamos National Labs). Employees of these national labs often need a graduate degree to advance in their careers, and thus they often choose to go back to school as experienced or mature students. The NSME program is ideal for these students as they get to use the interdisciplinary skills and knowledge they have learned on their jobs in their academic career. The NSME program also does not have a high requirement of courses that students need to take, and our qualifying exam tests students on research and design of experiments rather than on fundamental undergraduate knowledge like other departments. National lab students can also perform their research on their current research at their job as long as it can be disclosed to the public. To accomplish this students need a UNM faculty advisor to act as their academic mentor. This is often an attractive option for students as they can get paid from their national lab job and do their research on the same subject. However, currently we do not perform any special recruitment other than word of mouth. The current administration will send annual flyers to departments such as MESA at SNL to try and recruit employees to come back to UNM and NSME for MS or Ph.D degree.

4B: Admissions*:*

The general admission requirements described in the Graduate Program in this Catalog apply to the NSME program. Applicants who plan to apply to the NSME program must have a bachelor's degree in a STEM field. All incoming NSME students should meet a minimum level of competency indicated by have >3.0/4.0 GPA and have taken basic courses such as (Differential equations, 1 year of physics, and physical chemistry course). If needed, incoming students who are otherwise qualified may take these fundamental courses during their first semester and pass with a B or better or by taking and passing an equivalency exam that certifies their mathematical ability.

The students are required to apply through the graduate studies (online) and select the NSME degree they are applying for. The application documents are described in detail below. Students need to apply by July 15 for the Fall, November 10th for Spring, and April 29th for Summer (domestic) or Jan 1st for summer (international). Once the application is received all NSME Management are allowed to review the application and submit their feedback. The admission subcommittee which consists of Director and Associate Director will then review the feedback and make a decision on rather to admit the student or not.

NSME Application Process

The general application process for domestic and international students is described in the NSME Handbook. The following documents are required for each applicant:

1. Application/ Residency Form
2. Official Transcripts
3. Letter of Intent from the applicant about why this program is of interest. (Approximately 1 page stating the rationale and motivation for wanting to join the NSME Program.)
4. Three letters of recommendation.
5. GRE entrance examination scores sent directly from testing agency (no longer mandatory but optional)
6. Any other materials that are relevant to this application, such as experiential credit and CV.

Shared Credit Application Process:
Students from UNM who have been accepted into the shared credit program do not need to submit a GRE, letter of intent, or reference letters, as they had to submit these at the time of applying for the shared credit option. Typically, most shared credit program applicants are accepted into the program as they are currently participating in graduate studies, but they still must apply to be officially in the NSME program.

M.S. Admission and Advising roles
The Admissions Subcommittee reviews applications and makes admission decisions. Selected applicants are sent a notice of acceptance and international students are given the Amigo Scholarship offered by UNM which allows international students to get in-state tuition rates. Students are encouraged to meet with the program director or program administrator to discuss fellowship opportunities, class enrollment and UNM standard procedures such as the details of becoming a student, obtaining an ID card and procedures for enrolling in classes.

NSME Ph.D. Application and Admission Process
For prospective doctoral students, the process of applying and being selected is the same as for applicants to the M.S program, with the Admissions Subcommittee assuming responsibility for reviewing applications and selecting candidates. Applicants who plan to apply to the NSME program must have a bachelor's degree in a natural science or engineering field. Ph.D candidates are encouraged to contact potential mentors prior to applying to determine if the faculty member has an RA position available to support the student. In the past we have tried to offer support to students in their 1st semester by offering RA positions to exceptional applicants funded through NSME to help the student transition into their research roles with the faculty, but we cannot guarantee this every semester as it depends on current budgets.

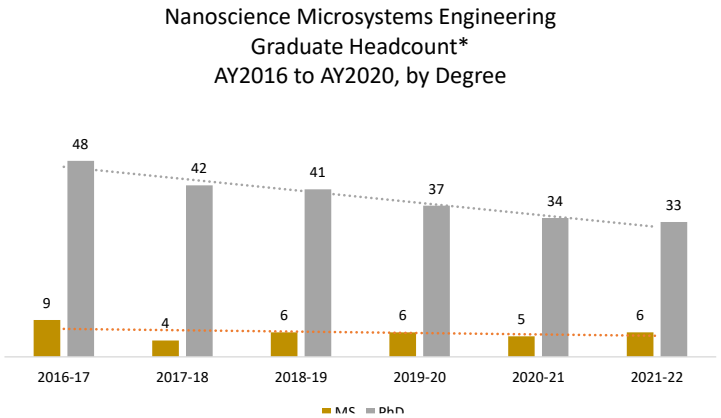
Transfer Student Credits:
Students transferring from another accredited university are allowed to transfer credits to count towards their degree and details of the process are determined by the UNM graduate studies and can be found in the UNM catalog. Transfer courses counting towards degree requirements can be approved by the Director or Associate Director of NSME.

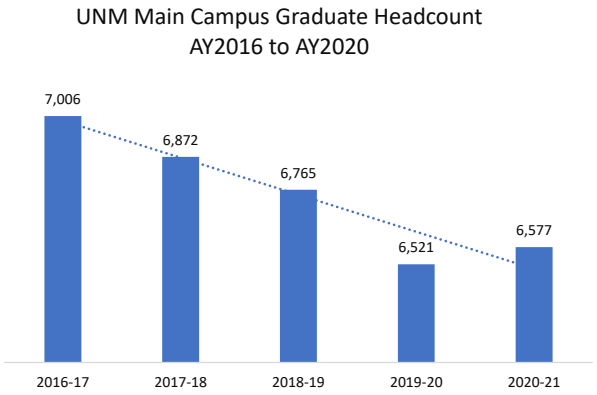
M.S and Ph.D students are encouraged to meet with the APC each year to discuss progress towards their degree, lab productivity, and goals. Once accepted all 1st year students will participate in an orientation with the APC, Director, and Associate Director, who will introduce them to UNM, graduate studies, NSME program, timeline of degree plans, curriculum, etc… The NSME administration also invite and encourage faculty members to attend to get up to date information about the degree requirements and funding of students.

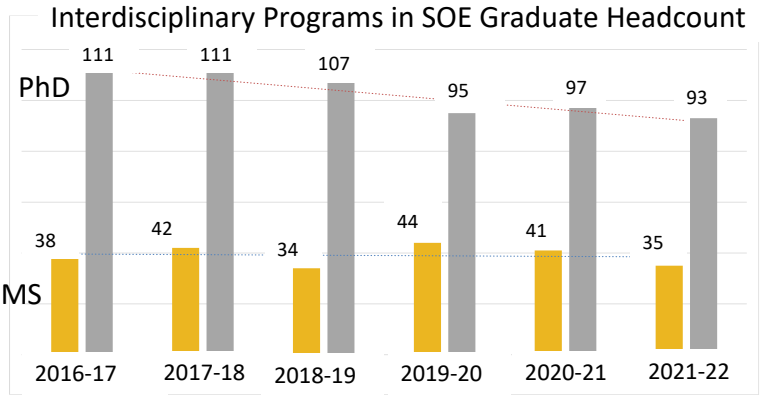
The admission process is relatively standard amongst various institutions, we have received notification from students who would prefer to remove the GRE requirements. The administration is currently looking into options which would waive this requirement if students had a high GPA (>3.5) from an accredited university.

4C: Data.

The enrollment head count for the NSME program over the past 6 years has declined as shown in the figure below but this is consistent with UNM graduate enrollment. The decline in enrollment within the NSME is believed to be due to 1) decline in overall graduate enrollment at UNM and 2) the addition of the BME graduate program has given students alternative interdisciplinary programs to choose from. However, the figure also demonstrates that the total headcount in the three interdisciplinary programs associated with SOE (OSE, BME, and NSME) demonstrate a similar trend, where the PhD enrollment is decreasing while the MS enrollment is relatively consistent over the past six years. The MS program has high PhD/MS enrollment ratio of 5.5, where most degrees are near 1. Therefore, we would like to increase MS enrollment through recruiting, shared credit programs (offering quick turn around times), and development of an MS online option.



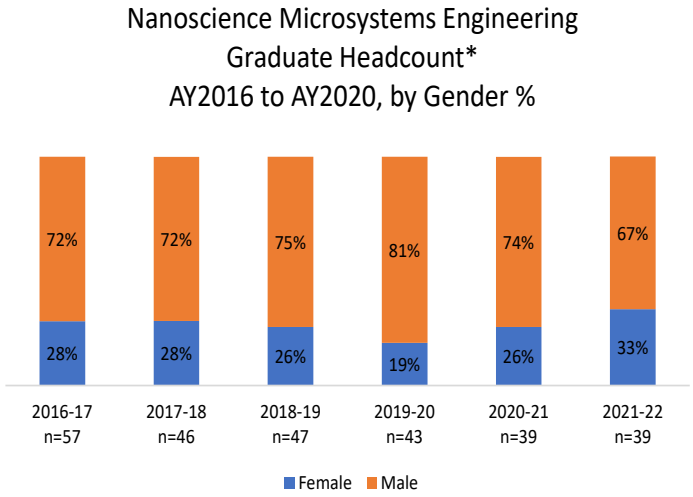


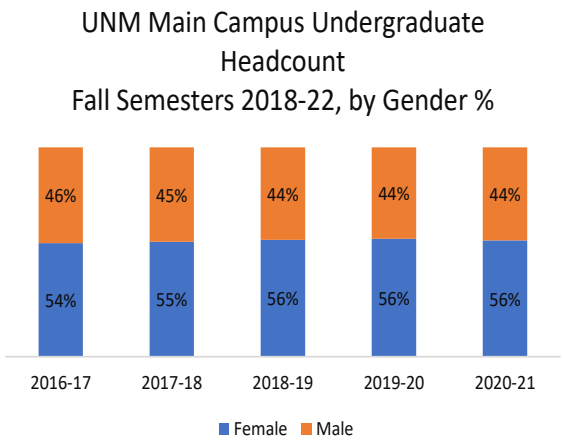


Demographics of NSME:

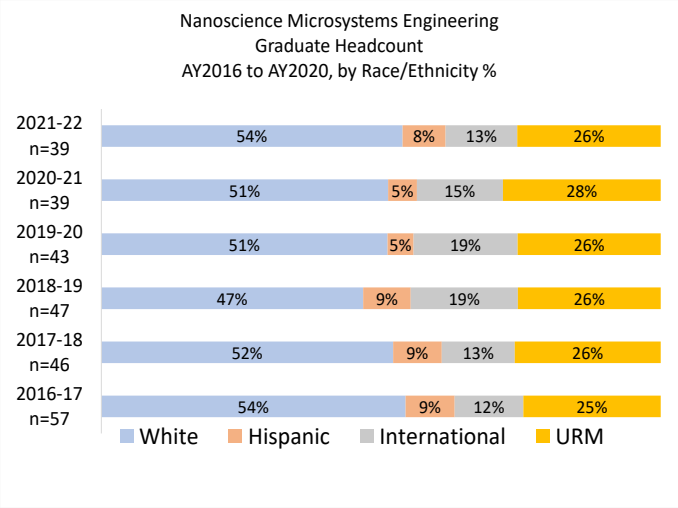
The figure below illustrates the relatively high female enrollment of the NSME program. According to Society of women engineers the average female enrollment in engineering is 14% in 2021 which is an increase from 9% in 1990 and 11% 2010. However, enrollment in A&S such as chemistry or biology have much higher female enrollment of 32% and 48% respectively. Over the past six years our average female enrollment is 27% and in 2021-2022 our enrollment has increased to 33%, which is comparable to national

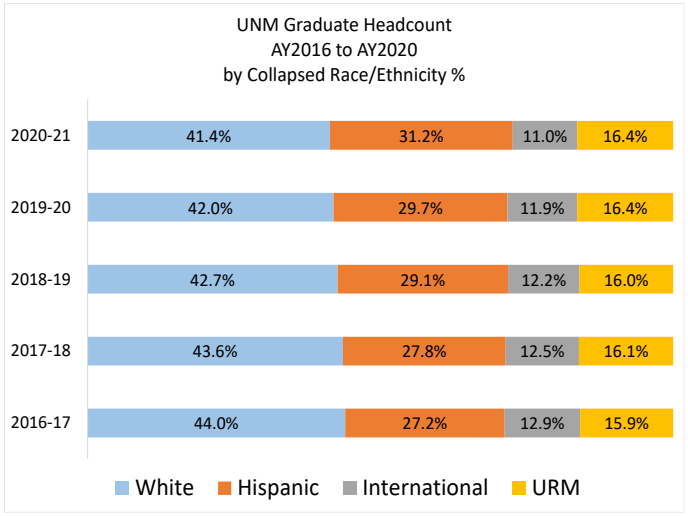
averages for chemistry. This is low when compared to UNM undergraduate enrollment which has 56% female enrollment, but in general engineering and sciences traditionally have lower female enrollment. To compare the SOE in 2021-2022 had 21.9% of MS and PhD degrees awarded go towards female students. However, the NSME administration is dedicated to continuing to increase these values by performing outreach events to get K-12 students interested in STEM.



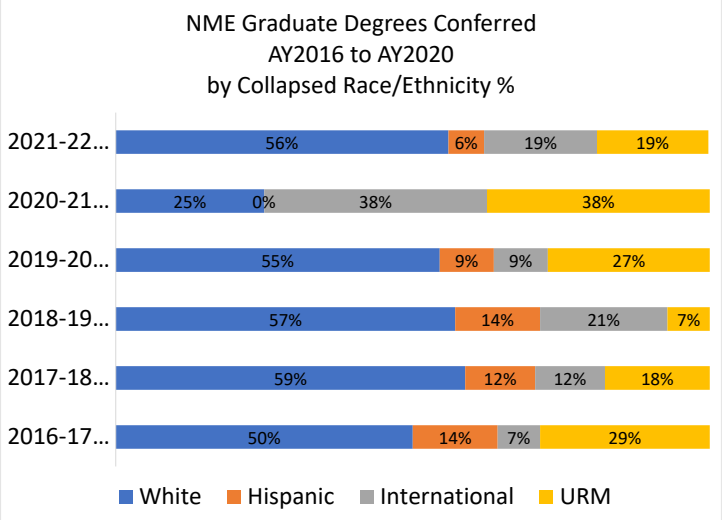


The ethnic demographics of the NSME program compared to UNM is provided below. The majority of the students in NSME are white and the numbers are relatively consistent, we have a large number of underrepresented minorities with an average over the past six years of 41.2%. The Hispanic enrollment is relatively low compared to the high Hispanic enrollment at UNM at only 9%. In 2020-2021 the degrees conferred within the SOE had 39.6% white, 25.1% Hispanic, 8.5% URM and 24.7% international. According to this comparison the NSME program has similar international demographics and slightly higher URM, but a significantly lower Hispanic and a higher white enrollment compared to SOE graduate programs. Comparing the NSME to the OSE and BME interdisciplinary program the demographics are similar. OSE had 44.4% white, 11.1% Hispanic, 11.1% URM, and 33.33% international. The BME program had 42.9% white, 28.6% Hispanic, 0% URM, and 28.5% international. The NSME program will focus on increasing Hispanic enrollment which will be accomplished through working with ESS and other programs at UNM to promote nanoscience and interdisciplinary programs. Another way in which we plan to increase Hispanic enrollment is to try and target URE in NSME labs, which will take advantage of the high Hispanic enrollment that UNM has for undergraduates and hopefully increase their interest in NSME-based research.





The conferred degree demographics breakdown had similar results as the enrollment as retention in the NSME program is high and is illustrated below.



Graduation time to degree:

The average time students take to get a MS degree in the NSME program is **2.25 ±1.33 years**. This can be further broken down into options. Option III (coursework) takes on average 2.64 years), option I (thesis) takes on average 2.58 years, option II (project) takes on average 2.56 years and the PSM takes on average 1.33 years because we had an accelerated program early on in the NSME program but the last graduate in the accelerated program was in 2014.

The average time students take to obtain their PhD degree is **5.58 years** with some students requiring their PhD in 2.5-4 years while some students took >10 years but removing the 10% outliers we get an average time of 4.98 years. This is also highly dependent on the students prior experience as some students go directly towards Ph.D after their BS and typically require more time to finish courses and get research experience. On the other hand, some students who get their MS and then join PhD typically finish in fewer years from being admitted into the PhD program.

Retention:

The NSME program has a high retention rate of approximately **89.3%**. This was determined by counting the number of enrolled students and the number of inactive students that never finished their degree or who are no longer pursuing their degree. Although roughly 9/10 students who enroll in the program finish their degrees the current administration would like to continue to improve these numbers. We believe the reason for this high retention rate is because of our curriculum, we let students take problems courses to replace technical electives. Therefore, students get to spend more time doing research and obtaining hands-on skills rather than focusing on courses.

4D: Advisement Practices

Advisement of students in the NSME program is performed by the APC and the students faculty mentor and COS, who can suggest technical electives for the student to take to help them in their research. Students are encouraged to meet with the APC at least once a year or if they have questions regarding courses or curriculum. Students are allowed to take any 500+ level STEM course to count towards their technical elective requirements. The Director can approve any course that is outside the STEM area. The qualifying exam committee can also suggest or make it mandatory for students to take courses in a particular area as part of a conditional passing of the exam. In addition, COS members can suggest courses after the comprehensive exam that would benefit the students research. To date we have not had any issues with students in regard to advisement, and students often praise our advisement methods and clarity.

4E: Student Support Services

The NSME program tries to offer research assistant positions in the 1st semester for incoming Ph.D students to offer financial support during their transition into the program, but we currently can only offer 1-2 per year, and due to current budget cutbacks we will need to remove this in the coming years. Currently, there is no teaching assistant positions, although the NSME 519 course is a lab which before 2021 had three 4-hour sessions each week, and in 2022 we had an increase in students which required five 4 hour sessions. This in addition to teaching lecture is a large workload for the instructor. Since the course is cross listed with mechanical engineering course ME 519, the ME department covers a TA at 10 hours/ week or FTE 0.25. Up to 2021 this has been acceptable, but as enrollment increases we need to cover the additional hours of workload. Since the course is a core requirement for NSME the administration feels we should cover a 2nd TA at 10 hours per week or cover the other 0.25 FTE, but we currently are not given any financial support for TA's. In fall 2022 we submitted a proposal to the provost to increase budget to account for this. In the past enrollment in NSME 519/ME 519 has been about 50% NSME and 50% ME. The increase in enrollment is believed to be due to the new Microsystems Concentration offered by ME BS degree.

The APC and Director of NSME help support students to try and find faculty mentors and are willing to offer support in helping student obtain jobs by offering reference letters. Faculty are also encouraged to help students find financial support from research assistantships to industrial external work. The NSME program does not have any undergraduates, but we promote the program to undergraduates in hopes they will apply to the program, and our faculty often participate in REU programs. In this case we work with the Engineering Student Success Center (ESS) who aim to help support students find jobs or research opportunities, but this is maintained by the SOE.

4F: Graduate Success

As an Academic program our ultimate goal is to educate and provide skills for our students so that they can have a successful career and provide value to their employer. However, this can be difficult to assess as after our students finish their degree they often do not communicate with us to know how they are doing. In the NSME program we have contacted past students to provide feedback on the curriculum and to help us determine if we should modify the curriculum to better prepare our students. Being an interdisciplinary program this is even more difficult as students tend to get jobs in a wide variety of fields. Therefore our curriculum is designed to give students soft-skills that all employees are interested in as well as providing them with research and design of experiment skills through their research. We currently measure success based on the students ability to graduate and get a high valued competitive job in a quick time.

Our students have gotten jobs in semiconductor industry, medical device industry, national laboratories, national associations, and academics including but not limited to:

- National Laboratories
    - Sandia National Labs
    - Los Alamos National Labs
    - Air Force Research Laboratories
    - Oak Ridge National Labs
    - US Naval Research Labs
- Semiconductor or Microsystems
    - Intel
    - Micron
    - Medtronic
    - Analog Devices
    - Broadcom
    - Skyworks
    - Raytheon
    - Honeywell
    - SpaceX
    - Cabot SMP
    - Skorpios
- Medical
    - Medtronic
    - Pfizer
    - Bio-Rad labs
    - Memorial Sloan Kettering Cancer Center
    - Lonza Medical
- National Associations
    - FDA
    - US. Patent
- Academics
    - MIT
    - University of New Mexico
    - University of Wisconsin
    - Texas A&M
    - University of Chicago
    - University of New South Wales (Australia)

- Misc. Industry
    - Applied Technology Associates
    - Skinfrared

Overall, our students have had good success at landing high quality jobs upon graduation. However, to improve on this the Director has written NSF IGE grants to create new courses in Nanoscience and Microsystems aimed to increase job readiness by creating a course setting that is meant to mimic a startup company to provide students with industrial like experience for those students who want to focus on research rather than obtain internships during their academic careers. The proposed funding has support from local semiconductor companies who would participate to provide curriculum feedback and hold mock interviews. If successful, these courses could be hosted by NSME program as technical electives for students who want to get more industrial skills and hands on microfabrication skills.

Criterion 5. Faculty

5A: Composition:

Faculty Composition: NSME is an interdisciplinary program, which does not have its own faculty but instead relies on faculty from various schools and departments to participate in the program. Over the past 10 years there has been 92 faculty members at UNM that have participated in the program by mentoring graduate students or teaching courses. The faculty have very diverse backgrounds from four different schools and numerous departments as listed below:

1. School of Engineering (45 faculty):
    a. Chemical and Biological Engineering (19 faculty)
    b. Civil and Construction Engineering (6 faculty)
    c. Electrical and Computer Engineering (10 faculty)
    d. Mechanical Engineering (6 faculty)
    e. Nuclear Engineering (1 faculty)
    f. Computer Science (3 faculty)
2. School of Arts and Science (29 faculty)
    a. Earth and Planetary Sciences (5 faculty)
    b. Physics and Astronomy (7 faculty)
    c. Biology (3 faculty)
    d. Chemistry and Chemical Biology (12 faculty)
    e. Mathematics and Statistics (2 faculty)
3. Health and Science Center (17 faculty)
    a. Pathology (5 faculty)
    b. Pharmaceutical Sciences (3 faculty)
    c. Molecular Genetics Microbiology (3 faculty)
    d. Neurology and Neurosciences (3 faculty)
    e. Orthopedic Research (1 faculty)
    f. Cancer Therapeutics (1 faculty)
    g. Emergency Medicine (1 faculty)
4. School of Management (1 faculty)

The credentials of faculty who currently teach the five core courses are listed in **Appendix D**, which range consists of faculty in SOE (ME and CBE) as well as A&S (Physics and Biology). The faculty teaching the courses have degrees in Bioengineering, Chemical Engineering, Physics, Biology, Material Science

Engineering, and Chemistry (three from SOE and three from A&S). The faculty consists of 17% of female faculty and consists of full professors and junior faculty (including the Director who is an Assistant Professor (up for tenured in 2022-2023). Since all faculty who teach the courses have primary positions in their home department it can be difficult to maintain faculty to teach these courses, especially if faculty go on sabbatical or retire. In fall 2023 one of the faculty who teaches NSME 518 is going on sabbatical and we reached out to CBE Chair to determine if he had any faculty who could teach the course. Luckily, we were able to find a replacement through a Research Professor position, or else we would have had to cancel the course and students would need to wait a year to take the course or an alternative equivalent course could be recommended by the administration.

NSME Administration Background: The Director of NSME (Nathan Jackson) has his primary position in Mechanical Engineering Department (SOE) but has secondary positions in ECE and CBE. He has backgrounds in Bioengineering (neuroscience), Material Science, and Microelectronics, and his primary research focus is on Microsystems, and he has background in industry as well as academia. To compliment the Director the Associate Director resides in A&S and has a primary position in Chemistry and Physics. The Director is an experimentalist whereas the AD works more on computational and theoretical.

5B: Course-Load:

The course loads of faculty are determined by the departments and university, and recently the faculty have unionized which are also in the process of changing the course load requirements. The course loads for assistant professors in the SOE are determined by the individual departments but typically are either 1:1 or 2:1, tenured professors conducting research are typically 2:1 and professors who are not actively involved in research typically teach 3 courses each semester. However, since NSME is not a department and we don't have faculty positions we rely on courses being cross listed with the faculties department so that they get credit for teaching a course within their department, or we work with Chairs of departments to allow faculty to teach courses and have it count towards their course load. An alternative is that we have adjunct or research faculty teach courses and pay them for their commitment. Currently our five core classes are taught by different faculty, so we don't have any single faculty member teaching more than one core class. The faculty to student ratio is typically around 1:15 for NSME students in our core classes, however with cross listing the courses can be larger, and we also get students outside of NSME program taking our courses as electives so courses can have around 1:20-25 ratios. Currently the faculty to student ratio is relatively low which leads to good interaction between faculty and students and students-to-students, so students get to know the faculty and their fellow students. However, the administration would like to increase enrollment to allow the program to continue to grow, and with growth the faculty to student ratio will increase. We would like to keep the ratio to around 1:15 or 1:20 at the most, so if the program increases enrollment, we will likely need to offer courses more often or have multiple sections which would require higher budget for faculty to teach the courses.

5C: Professional Development:

The professional development of faculty members is mostly handled by the departments. NSME selects faculty that have research activities that directly link with the core classes focus to ensure that students are getting the most up to date education experience. If there is a vacancy in instructing a core class the NSME director reaches out to Department Chairs for assistance in finding a suitable replacement. As for getting junior faculty involved in NSME the director looks at current research and reaches out to faculty to participate in advising students. During the students application process we look at their interests and reach out to faculty who might be interested in advising the student.

The NSME program relies on its instructors to provide up to date information regarding their courses. For instance, NSME 519 focused on Advanced Nano and Microsystems Engineering is taught by Prof. Jackson whose research is focused on Microfabrication and Microsystems, and he is constantly altering his lectures with up-to-date research topics for students. Research in NSME area is up to the individual faculty, as we rely on faculty to get funding to support research efforts and students in the NSME program. Academic program support is provided by the APC. Mentoring of students in their research is provided by the individual faculty and any issues that arise between students and faculty is handled by the Director. Regarding hiring new faculty, the NSME program does not hire faculty, but the Director is willing to provide opinions and recommendations on new hires from various departments who are hiring new faculty in the Nanoscience or Microsystem area, as we would like to increase our diversity of faculty involved in NSME such as increasing female and underrepresented faculty.

Criterion 6. Research, Scholarship, & Service

6A: Scholarly & Creative Works

The NSME program consists of a diverse faculty as demonstrated in Criterion 5, that spans four different schools and over 19 different departments. The 92 faculty that have been involved in the NSME program over the past 10 years has an average **h-index of 31.9** and an average citation/faculty of **2069 since 2018 or 414 per year**. Over the past 10 years the faculty have received 1878 externally funded proposals. The faculty involved in the program have gotten numerous awards such as NSF CAREER, AFO SR Young Investigator, ONR Young Investigator, Innovation awards as well as numerous other awards. The faculty involved in the program are highly involved in academic and innovative research. The largest scholarly works from our faculty are mostly focused on material science as related to nanoscience or microsystems as well as nano-bio sciences. The diversity in our faculty is a big strength for our program as it provides students with multiple research topic options, and it provides the students with diverse knowledge, skills, and experience.

6B: Research Expenditures

The faculty involved in the NSME program all have primary departments that they report to. Since 2012 the faculty involved in the NSME program have obtained 1878 externally funded projects which generated **$208,474,302.** Which averages to **$20,847,430/per year** or $**226,602/per year per faculty**. However, faculty are also involved in their own departments, and it is very difficult to track how much of the money went to funding research or students involved in the NSME program. The NSME program relies on faculty getting funding to support students and their research, therefore in order for the NSME program to survive it requires faculty to continue to obtain funding, as the program currently has no money to support students through TA or GA positions. Therefore, the faculty generated revenue is critical for the success of the program. The NSME program gets funding from UNM upper admin (Provost and A & S and formerly SOE) to help cover courses and administrative costs, but the money is not used to cover research, equipment, consumables, or student support.

6C: Research Involvement

The NSME research activities are heavily involved with research labs and centers. Several of our students are employed at the nearby national labs (SNL, LANL, and AFRL). Some students work at the national labs and perform research activities with an NSME mentor, others choose to perform their thesis or

dissertation research at the national labs, but if this option is chosen the student must have a UNM faculty advisor/mentor (chair of their committee) to help guide them through their Ph.D or MS degree requirements. We encourage the student to select a UNM advisor that has similar research needs so that the UNM advisor can have an active role in the research performed at the national lab. In addition, some of the faculty members involved in the NSME program are full time staff members of the national labs but hold adjunct or research professor positions at UNM. Some of the instructors who teach the core classes have positions with SNL, which gives students the advantage of providing our students with real world experience.

NSME faculty are also members of various research centers around UNM such as Center for High Technology Materials (CHTM), Center for Microengineered Materials, Center for Advanced Research Computing (CARC), Center for Biomedical Engineering (CBME), and Manufacturing Training and Technology Center (MTTC). This allows our students to have access to diverse set of equipment and knowledge. In addition, many of our faculty regularly get funded proposals with the Center for Integrated Nanotechnologies (CINT) which is part of SNL and LANL. Funded projects do not have any monetary value but it allows our students to have access to the equipment at CINT, which includes e-beam lithography, cleanroom equipment, advanced nanoscience characterization etc… CINT proposals are open to any faculty around the US to apply, but since we are local our students have access to the equipment 24/7, and students get to interact with CINT faculty which gives them even more diversity and exposure to research.

6D: Student Opportunities

Ph.D students are obviously highly involved in research activities as required for their degrees. M.S students involved in the NSME program can choose the thesis option which would have them be involved in the research opportunities. MS students obtaining a degree from the coursework option have the opportunity to get involved in research by taking research problems course instead of technical electives, this way students get some exposure to research for their CV's without the high time consumption of a thesis option (the problems course is dependent on student finding faculty who are willing to participate). We encourage all students to be active in extracurricular activities especially outreach events or organizations such as CHTW (promotes females involved in CHTM or any STEM), graduate and professional student association (GPSA), society of women engineers (SWE), and numerous other organizations. At orientation we introduce the students to these organizations and give them a chance to talk to our students to provide them with information and how they can get involved.

Undergraduate research opportunities exist within NSME even through we do not have an undergraduate degree option, but the administration encourages faculty to offer undergraduates research opportunities in their lab, as this provides students with experience as they get to learn how to apply their knowledge from courses. In addition the experience will help promote the program as students will learn about nanoscience and microsystems to determine if it is an area that they maybe interested in, in the future. The NSME administration works with ESS to find placements of students in research labs. The faculty of NSME are also involved in several URE summer programs such as QU-REACH which brings students from New Mexico to work on quantum-based projects. Faculty are also involved in AEOP (an undergraduate/high school program sponsored by Army Research Office). The admin would like to offer more support to URE but currently we rely on funding from our faculty to help support students.

6E: Community Service

Faculty members are encouraged through NSME, their own departments, and UNM to be an active member in the community (locally and globally). This involves both the scientific community, academic community, and local community. In the scientific community our faculty are highly involved in multiple professional organizations including IEEE, American Vacuum Society (AVS), American chemical society (ACS), ASME (American society of mechanical engineers), as well as other medical societies. In addition to being involved in professional organizations our faculty are also involved in various journals as associate editors and editors of tier 1 journals and are active high ranked conference steering committees and chairs of conferences in the related field. The faculty are also involved in proposal grant reviews from various funding sources such as NSF and NIH.

The Director (Nathan Jackson) is highly involved in the scientific and academic community. He is a technical committee member for IEEE MEMS as well as IMECE (MEMS Division), and he has been the session chair for Force sensors, powerMEMS, Optical MEMS, and Microfluidics. He was also a technical committee member for IEEE Nano and chair of the Piezoelectric Materials session in 2018. He is also on the editorial board for Micromachines and part of the IEEE PowerMEMS conference, and has been an active proposal reviewer for EU-Horizon 2020. He is also an active member for American Society of Engineering Education (ASEE) where he has published several papers focused on education using microfabrication, and he is the Co-PI on an ATE NSF funded project aimed at training community college students on microfabrication to become microsystem or semiconductor manufacturing technicians. He has also participated in mentoring and judging local and statewide science fairs and outreach events aimed to promote UNM STEM programs.

In addition to the vast academic and scientific services, we encourage all of our faculty to engage the local community around Albuquerque and New Mexico to participate in outreach events and to be an active member in the community. Our faculty participate in various outreach events associated with NSF proposals and Career projects as well as other events such as lecturing or speaking at local scientific events.

Criterion 7. Peer Comparisons

7A: Analysis *(Table **Appendix E**)*

The NSME program is an interdisciplinary program, currently at UNM there are two other interdisciplinary programs associated with SOE (Optical Science Engineering and Biomedical Engineering). Both of these other programs offer MS and Ph.D degrees. The OSE has been around for >40 years and the BME program was established after the NSME program in 2010. Numerous nanoscience and microsystems programs and departments have been developed or are being developed at various universities across the country. A brief list of some universities who have started nanoscience programs is listed in the figure below. In 2009 only 15 universities offered graduate degrees in nanotechnology. Some of the early versions of nanotechnology degrees were from North Dakota State University, SUNY Albany, University Washington, UCSD and UNM. In addition, there are numerous universities who offer Microsystems degree mostly as a concentration in either electrical engineering or mechanical engineering, but there are some that have standalone degrees such as Northeastern University, University of Michigan, Rochester Institute of Technology. Some universities have created entire departments focused on nanoengineering such as UC San Diego https://ne.ucsd.edu/graduate-programs/degree/nanoengineering, which offer a MS and Ph.D. However, UCSD department is not interdisciplinary as it resides and has faculty only in engineering. The curriculum is similar to the NSME program as they require five core classes listed below. However, they are a department and have faculty

that have primary positions in nanoengineering. They offer a wide range of technical courses, depending on the students interest and research focus, which is due to them being a department where faculty can teach specific courses. UCSD nanoengineering was created from the Chemical Engineering in 2009.

1. **NANO 201: Foundations of NanoEngineering I: Introduction to NanoEngineering (4).** Understanding nanotechnology, broad implications, miniaturization: scaling laws; nanoscale physics; types and properties of nanomaterials; nanomechanical oscillators, nano(bio)electronics, nanoscale heat transfer; fluids at nanoscale; machinery cell; applications of nanotechnology and nanobiotechnology (*similar to NSMS 510*).
2. **NANO 202: Intermolecular and Surface Forces (4).** Development of quantitative understanding of the different intermolecular forces between atoms and molecules and how these forces give rise to interesting phenomena at the nanoscale, such as flocculation, wetting, self-assembly in biological (natural) and synthetic systems (*taught to some extent in NSMS 510*).
3. **NANO 203: Nanoscale Characterization (4).** Examination of nanoscale characterization approaches including imaging, scattering, and spectroscopic techniques and their physical operating mechanisms. Microscopy (optical and electron: SEM, TEM); scattering & diffraction; spectroscopies (EDX, SIMS, mass spec, Raman, XPS, XAS); scanning probe microscopes (SPM, AFM); particle size analysis (*Similar to NSMS 512*).
4. **NANO 205: Nanosystems Integration (4).** Scaling issues and hierarchical assembly of nanoscale components into higher order structures which retain desired properties at microscale and macroscale levels. Novel ways to combine top-down and bottom-up processes for integration of heterogeneous components into higher order structures (*Similar to NSMS 519 and 518*).
5. **NANO 206: Nanomanufacturing (4).** Fundamental nanomanufacturing science and engineering, top-down nanomanufacturing processes, bottom-up nanomanufacturing processes, integrated top-down and bottom-up nanofabrication processes, 3-dimensional nanomanufacturing, nanomanufacturing systems, nanometrology, nanomanufactured devices for medicine, life sciences, energy, and defense applications (*similar to NSMS 519*).

Louisiana Tech University have a standalone Nanosystems Engineering degree for undergraduates, and offer a Micro and Nanoscale Systems Engineering degree for Ph.D and they also have a molecular science and Nanotechnology Ph.D degree option. For the Micro and Nanoscale Systems Engineering Ph.D their curriculum is provided below. They have three core classes in math and statistics that all engineering students need to take then they require six concentration courses. The big difference between their options and UNM is half of their required courses are based on microsystems and the other half is on nanotechnology, whereas the NSME program currently mostly focuses on nanotechnology with only 20% of required courses that focus on microsystems. This feedback has also been illustrated by several students at UNM and is something we are considering altering in the future and would value the input from the reviewers.

Course Category	Number	Course Name		SCH
Core Courses	MATH 574	Numerical Solutions of PDE	3	9
	ENGR 641	Formulation of Solutions to Engineering Problems	3	
	STAT 620	Theory of Probability	3	
Concentration Courses[1]	MSE 501	Fundamentals of Microfabrication Processes	3	12
	Select three of the following five courses			
	MSE 502	Microsystems Principles	3	
	MSE 504	Advanced Materials for Micro/Nano Devices & Systems	3	
	MSE 505	Nanotechnology Principles	3	
	MSE 506	Micro/Nano Scale Materials Measurements & Analysis	3	
	MSNT 506	Nanofabrications by Self-Assembly	3	
Qualifying Examinations[2]	ENGR 685	Written Qualifying Exam	0	
	ENGR 686	Oral Comprehensive Exam (pre-requisite ENGR 685)	0	
Doctoral Seminar	ENGR 611	Dissertation Enhancement Seminar (taken three times)	1	3
Directed Study	ENGR 650[3]	Doctoral Directed Study (take up to 6 SCH)	6	6
Electives	Select six (18 semester hours) courses from electives list or others approved by advisory committee			18
Research and Dissertation[4]	ENGR 651	Pre-Candidacy Doctoral Research	1-9	9
	ENGR 751	Post-Candidacy Dissertation Research	1-9	9
				Total 66

University of Washington offer a concentration in Nanotechnology but the MS and PhD degrees are still associated with a department within the school of engineering. UW program started out similar to NSME as it started from an IGERT. NDSU offer a graduate program in Materials and Nanotechnology which is interdisciplinary (Engineering and A&S as well as Center for Nanoscale Science). The NDSU program is similar to the UNM NSME program, in that it is interdisciplinary and offers both M.S and Ph.D degrees, and the faculty members involved in the program all have primary home departments. However, NDSU program is associated with a research center whereas UNM's program is not.

A list of other universities with nanotechnology graduate degree options are given below. The curriculum of the various universities is similar to the UNM NSME. There are several differences 1. Degrees with microsystem tend to have more microsystem course options than NSME, 2. Most universities require 1 more core class and many more technical courses and they have a wider selection of core classes associated with their program, at UNM we have a wide range of courses but they are typically offered by various departments and have prerequisites which some students might not have met.

As for enrollment numbers it was difficult to obtain this information from other universities, but we compared the NSME program to various SOE and interdisciplinary programs at UNM which can be seen in **Appendix E.** Compared to the BME program we have similar overall enrollment as of 2022 NSME has 39 students and BME has 35 students. Looking at various SOE departments graduate enrollment the NSME program is similar numbers to CBE (35 graduate students), but far less than ECE (263 graduate students). Most departments and programs at UNM have more MS students than Ph.D students for instance ME (76 MS and 23 PhD), ECE (155 MS and 108 PhD). BME program has a near equal amount of MS to PhD students (16 MS and 19 PhD) similar numbers are demonstrated within the CBE department (17 MS and 18 PhD). The NSME program is significantly different in this aspect as we have far more Ph.D Students than MS students (6 MS and 33 Ph.D). This is unusual and could be interpreted in a couple ways 1. Our program is good at attracting Ph.D students or 2. We don't attract enough MS students. The current Director's interpretation of this is we have a large number of Ph.D students but we need to do a better job of attracting MS students as we should have at least 50% MS students. We hope to change this by altering our recruiting of undergraduate students at UNM as well as creating shared credit programs with A&S departments, which will offer a 1 year MS degree option. In addition, the administration is trying to determine methods of creating online MS option which we believe would significantly increase our MS enrollment by offering degree options from students across the country.

There are several factors that make UNM NSME program unique. NSME is an Interdisciplinary Program that offers three graduate degrees in Nanoscience and Microsystems: MS, PSM and Ph.D. It is the only program that spans four colleges: Arts and Sciences, Engineering, School of Medicine and the Anderson

School of Management. Affiliated faculty from Departments in all these Colleges are actively engaged in teaching core courses, program management, program and student evaluation and examination committees. At UNM, the NSME has one of the most active Graduate Student Associations. The GSA is actively involved in all facets of the program: program evaluation, new student orientation, course assessment and community outreach. The NSME program has been one of the most active graduate programs on campus in terms of community events and outreach. While the NSME program is not associated with a center specifically for nanotechnology, the program has affiliated faculty, and students working in the research laboratories of several research centers with nanoscale projects, namely the Centers for: MicroEngineered Materials (CMEM), Emerging Energy Technologies (CEET), High Technology Materials (CHTM), BioMedical Engineering (CBME) and the UNM/SNL Advanced Materials Laboratory (AML). Unlike the traditional Departments at UNM, the NSME program does not have an associated undergraduate degree, and consequently all financial support for graduate students is provided through training grants, graduate assistantships from federally funded grants, or TA positions from other departments. Despite the lack of teaching assistant lines, first and second year graduate students have been successfully supported from a variety of competitive fellowship programs: NSF NSMS IGERT, NSF NSMS PSM Program, DoEd NSMS GAANN and the NIH CNTC (Cancer Nano Training Center), previously. But we would like to offer TA or GA positions for 1st and 2nd year PhD students to help provide financial support.

The other major difference between our Ph.D program compared to other UNM degrees or external degrees offered in similar areas is our program offers students the opportunity to substitute courses with research problems courses, thus students ultimately have the option of taking less courses which allows them graduate in a quicker timeframe as they can focus on their research. Students and faculty at UNM have illustrated that this option was very attractive in their decision to choose NSME over other departmental programs. However, the administration of NSME see courses as being critical to have students get a diverse fundamental knowledge and is considering increasing the mandatory TE by 1-2 courses, thus keeping the high interest in research but still providing students with more diverse knowledge and skills.

University of Albany - MD/PhD in Medicine and Nanoscale Science or Engineering

This first-of-its-kind dual degree program provides pioneering education and training in both medicine and nanoscale science research, preparing a new generation of professionals for exciting 21st century careers as world-class research physicians in the emerging science and practice of nanomedicine.

University of Albany - Nanoscale Engineering tracks for Ph.D. degree

CNSE's Nanoscale Engineering program provides corresponding skill and expertise in the design, fabrication, and integration of nanoscale devices, structures, and systems for the development and deployment of emerging nanotechnologies.

University of Albany - Nanoscale Science tracks for Ph.D. degree

CNSE's Nanoscale Science program provides the critical theoretical and experimental skill base and know-how for knowledge creation in the areas of nanoscale materials, structures, and architectures.

University of California, San Diego - Ph.D. Nanoengineering

Plans are currently underway to develop graduate curricula leading to the M.S. and Ph.D. degrees in NanoEngineering by 2011. Until NanoEngineering graduate programs are in place, students wishing to pursue nanoengineering as a graduate focus are encouraged to apply to related graduate programs in bioengineering, chemical engineering, and mechanical and aerospace engineering. Transfer to NanoEngineering will be considered upon approval of its degree programs.

University of New Mexico - Doctor of Philosophy Nanoscience and Microsystems

This exciting program bridges the distinct properties of the nanoscale to microsystem functionality. The integrated academic and research activities highlight our capabilities and unique breadth in materials synthesis and self-assembly, nanolithography, interrogative platforms, and functional micro/macrosystems.

University of North Carolina Charlotte - Nanoscale Science PhD Program

The Ph.D. in Nanoscale Science at UNC Charlotte is an interdisciplinary program that addresses the development, manipulation, and use of materials and devices on the scale of roughly 1-100 nanometers in length, and the study of phenomena that occur on this size scale. The program prepares students to become scholarly, practicing scientists who possess the critical thinking, methodological, and communication skills required to advance and disseminate knowledge of fundamental and applied nanoscale science.

University of Texas at Austin - Ph.D. Engineering Nanomaterials Thrust

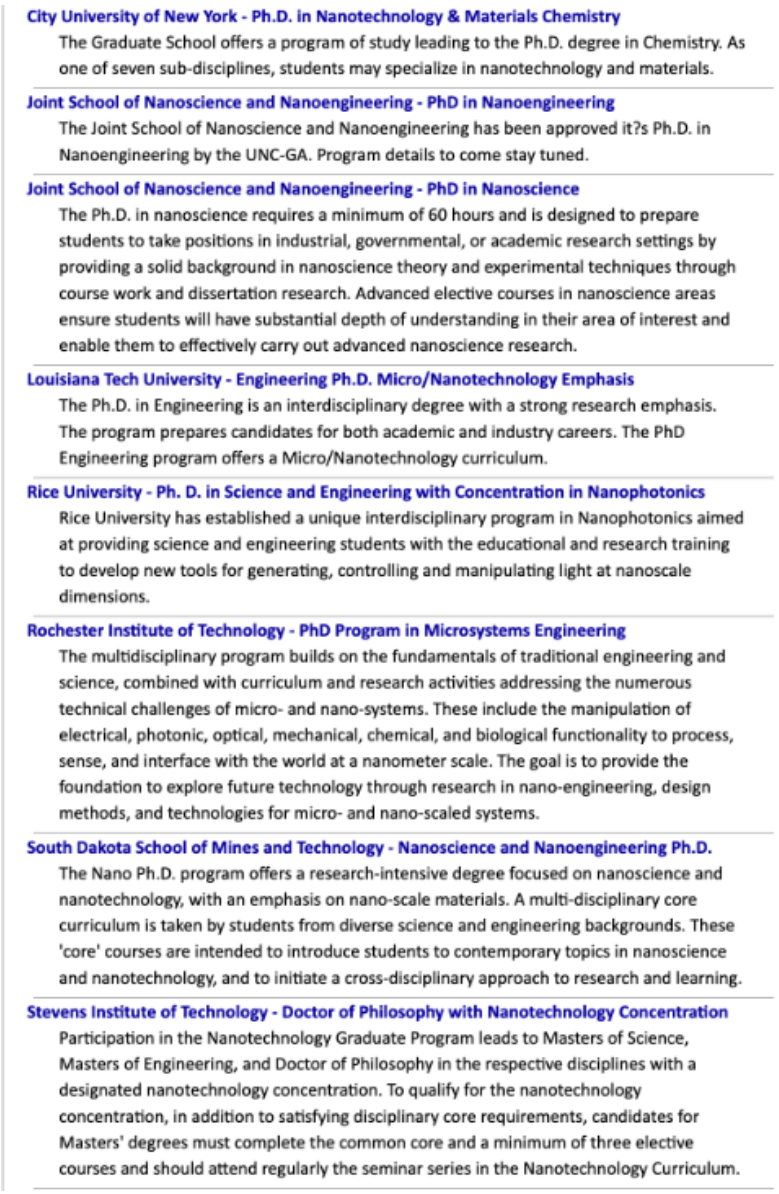
Students who have a strong background in any of the physical sciences or engineering disciplines are encouraged to apply to the Graduate Program in Materials Science and Engineering. MS&E students that select the Nanomaterials Thrust will take a sequence of courses from basic to advanced designed to train them in the fundamentals of materials science as well as critical skills in processing, characterization and applications of nanomaterials.

University of Washington - Dual Degree Program in Nanotechnology

After admission to a participating department, graduate students can apply for our 'Option Ph.D. in Nanotechnology' program. Fulfillment of both departmental and Nanotechnology Program requirements will lead to a Ph. D. in Nanotechnology and the chosen discipline.

Virginia Commonwealth University - Ph.D. Nanoscience and Nanotechnology

The new program, which was developed by faculty in the VCU Departments of Chemistry and Physics, is designed to cross-train students in the physical sciences of chemistry and physics with particular focus on how the science changes at reduced dimensions. There is a potential for other departments to become more involved as the program develops.



City University of New York - Ph.D. in Nanotechnology & Materials Chemistry

The Graduate School offers a program of study leading to the Ph.D. degree in Chemistry. As one of seven sub-disciplines, students may specialize in nanotechnology and materials.

Joint School of Nanoscience and Nanoengineering - PhD in Nanoengineering

The Joint School of Nanoscience and Nanoengineering has been approved it?s Ph.D. in Nanoengineering by the UNC-GA. Program details to come stay tuned.

Joint School of Nanoscience and Nanoengineering - PhD in Nanoscience

The Ph.D. in nanoscience requires a minimum of 60 hours and is designed to prepare students to take positions in industrial, governmental, or academic research settings by providing a solid background in nanoscience theory and experimental techniques through course work and dissertation research. Advanced elective courses in nanoscience areas ensure students will have substantial depth of understanding in their area of interest and enable them to effectively carry out advanced nanoscience research.

Louisiana Tech University - Engineering Ph.D. Micro/Nanotechnology Emphasis

The Ph.D. in Engineering is an interdisciplinary degree with a strong research emphasis. The program prepares candidates for both academic and industry careers. The PhD Engineering program offers a Micro/Nanotechnology curriculum.

Rice University - Ph. D. in Science and Engineering with Concentration in Nanophotonics

Rice University has established a unique interdisciplinary program in Nanophotonics aimed at providing science and engineering students with the educational and research training to develop new tools for generating, controlling and manipulating light at nanoscale dimensions.

Rochester Institute of Technology - PhD Program in Microsystems Engineering

The multidisciplinary program builds on the fundamentals of traditional engineering and science, combined with curriculum and research activities addressing the numerous technical challenges of micro- and nano-systems. These include the manipulation of electrical, photonic, optical, mechanical, chemical, and biological functionality to process, sense, and interface with the world at a nanometer scale. The goal is to provide the foundation to explore future technology through research in nano-engineering, design methods, and technologies for micro- and nano-scaled systems.

South Dakota School of Mines and Technology - Nanoscience and Nanoengineering Ph.D.

The Nano Ph.D. program offers a research-intensive degree focused on nanoscience and nanotechnology, with an emphasis on nano-scale materials. A multi-disciplinary core curriculum is taken by students from diverse science and engineering backgrounds. These 'core' courses are intended to introduce students to contemporary topics in nanoscience and nanotechnology, and to initiate a cross-disciplinary approach to research and learning.

Stevens Institute of Technology - Doctor of Philosophy with Nanotechnology Concentration

Participation in the Nanotechnology Graduate Program leads to Masters of Science, Masters of Engineering, and Doctor of Philosophy in the respective disciplines with a designated nanotechnology concentration. To qualify for the nanotechnology concentration, in addition to satisfying disciplinary core requirements, candidates for Masters' degrees must complete the common core and a minimum of three elective courses and should attend regularly the seminar series in the Nanotechnology Curriculum.

Criterion 8. Resources & Planning

8A: Budget

In the early years of the NSME program 2007-2013 the program received its financial support from various funding agencies. However, over the past nine years we have been sustained through funding from Provost, SOE, A&S, as well as course fees and differential tuition. The table below illustrates the sources of revenue for the NSME program over the past five years. The SOE stopped providing financial support in 2021-2022 which also has continued in 2022-2023 (data not shown). The provost office started helping with financial support in 2020-2021 but the value decreased in 2021-2022. Overall, 2021-2022 we had approximately a 25% budget cut. Also, in 2021-2022 the course fees and differential tuition make up approximately 42.4% of our revenue. This is one of the reasons why the Director would like to increase enrollment so that we can increase our revenue to help support the program. The SOE former Dean also made a proposal request to Provost to increase differential tuition throughout SOE by having a modest increase compared to other universities. Currently, the differential tuition is $15.08 per credit and NSME

gets 80% of that ($12.06 per credit). The former Dean of SOE proposed to raise the differential tuition to $25.80 (or $20.64 per credit to NSME). This would have a big impact to small programs like NSME as it would raise our differential tuition by about 70% (ie. in 2021-2022 this would have resulted in an additional ~$22k annually). In addition, accelerated online MS degrees have even higher differential tuition return ~65% of tuition or around $233 per credit, so by creating an online MS degree in NSME we could increase our differential tuition by greater than 20x. This is one of the main reasons why the Director of NSME is looking at options to create an accelerated online NSME MS degree option.

Revenue	2017-18	2018-19	2019-20	2020-21	2021-22
Course Fees	$7,440.00	$8,280.00	$5,430.00	$5,160.00	$5,130.00
School of Engineering	$28,750.00	$28,750.00	$28,750.00	$28,750.00	$0.00
Provost	$0.00	$0.00	$0.00	$19,857.00	$18,626.00
A&S	$31,288.00	$31,288.00	$31,288.00	$31,288.00	$31,288.00
Differential Tuition	$16,085.00	$42,575.14	$35,069.51	$30,402.14	$31,693.00
Total Revenue	**$83,563.00**	**$110,893.14**	**$100,537.51**	**$115,457.14**	**$86,737.00**

The table below illustrates the expenditures of the NSME program over the past 5 years. In the past 2018-2021 we received more revenue that what we spent which went into reserves, but in 2021-2022 with the revenue cuts we exceeded our revenue and have been spending our reserves. There are a couple things to point out on this list. First the Director and Associate Director salary is very low covering <2 weeks of our annual time, and the SAC we receive is significantly lower than other interdisciplinary programs. The main expense increase in 2021-2022 was the RA positions we offered 2 RA (1 semester each), which cost approximately $38k counting tuition and fringe benefits. Also, our Admin cost significantly decreased as we now only pay our APC at 0.5FTE. One thing that was significantly cut due to budgets was the recruitment/outreach events which in 2017 was $7,346 and in 2021-2022 this decreased to $947. Another important item that is not listed is seminar cost as we currently participate in the CBE seminar and try to only bring in local speakers. However, if we create our own seminar and bring in about 50% out of state speakers the cost of this would be about $1500 per out of state speaker or about $12k per semester, so a year round NSME seminar would require a budget of around $24k. Overall we can cut the budgets to meet our current revenue by removing financial support to students and by continuing to decrease outreach and recruitment events as well as consumables for labs and course materials and by not having our own seminar series, and by reducing adjunct teachers for our core classes. But in the long run the Director feels that this will hurt the program, and ultimately his goal is to enhance the program to be one of the elite nanoscience and microsystems programs in the country, but to accomplish these goals more revenue is needed. In the past NSME prided its self on the significant outreach events it participated in and required students to participate in these events annually, but due to cutbacks in budgets this was one of the areas that could be reduced, but that affects student networking and soft skills that students need to succeed in the real world. The future budget proposal from the Director is discussed in more detail in the future budget options needed to continue to grow the NSME program. The Director is also investigating methods of getting funding for IGE NSF grants to develop new courses and curriculums which would help add more technical elective options to student and help support graduate assistantships to aid in development of these courses.

Expenses	2017-18	2018-19	2019-20	2020-21	2021-22
Faculty Salary - Director	$5,000.00	$5,000.00	$5,000.00	$5,000.00	$5,000.00
Faculty Salary - Assoc Director	$2,500.00	$0.00	$0.00	$0.00	$2,500.00
Faculty Salary - Adjunct	$0.00	$2,500.16	$0.00	$0.00	$0.00
Faculty Temp Part Time	$0.00	$0.00	$1,667.00	$3,333.34	$1,733.32
Administrative & Support Staff	$40,950.31	$41,709.41	$40,945.26	$31,868.86	$21,474.89
Website Support	$3,412.51	$3,848.79	$4,219.90	$4,219.85	$4,315.34
Fringe Beneftis	$0.00	$0.00	$0.00	$17,707.62	$21,239.80
Assistantships	$0.00	$2,500.00	$3,000.00	$11,040.48	$30,081.82
Student Tuition and Textbook Expense	$0.00	$35.99	$3,056.96	$1,191.00	$7,805.70
Scholarships Fellowships Gen	$0.00	$0.00	$0.00	$0.00	$1,512.90
Student Events, Outreach, Recruitment	$7,346.95	$5,095.35	$3,205.81	$62.48	$947.14
Conference and Guest Speaker Travel	$6,271.28	$2,683.09	$458.72	$0.00	$100.00
Promotional Expenses	$0.00	$670.00	$0.00	$500.00	$0.00
Instructional Materials & Lab Supplies	$5,061.75	$4,409.02	$2,197.19	$2,877.26	$2,761.62
Equipment	$80.00	$3,708.00	$3,629.00	$1,399.00	$1,013.70
Office Supplies General	$3,693.21	$4,541.22	$3,133.03	$0.00	$506.15
Computer Software and Supplies	$1,328.34	$1,052.54	$6,364.11	$5,375.41	$3,288.74
Office Expenses General	$418.01	$527.55	$411.98	$330.00	$871.20
University-wide Service and Foundation Surcharges	$621.63	$618.32	$580.07	$529.98	$620.70
Total Expense	**$76,683.99**	**$78,899.44**	**$77,869.03**	**$85,435.28**	**$105,773.02**

8B: Staff:

The NSME program currently has one staff member (Yvone' Nelson) who has the official title of Academic Program Coordinator. She is currently at 0.5 FTE for the NSME program and she is also 0.5 FTE for the BME program, with the same job title. The APC's responsibilities include:

- Academic Advising
- Budget and Financial Responsibilities
- Administration Documentation
- Recruitment, Outreach, and Public Relation Assistance
- Conference Room and Meeting Scheduling
- Day to Day Operations

Overall, the APC is responsible for the day-to-day operations. Ms. Nelson took over the position of NSME/BME APC in 2021. Currently the APC is asked to have a lot of responsibilities especially when only working at 0.5 FTE, and right now this is adequate but could be improved if we had another part time staff member to help with outreach or budget. However, the Director would like to have the program grow and increase enrollment and form an online MS option, which would require increased operations (budget, documentation, meetings, advising, and recruitment) which would require additional staff member to help support the APC.

8C: Advisory Board:

The NSME Program currently has an executive committee, administration, and management team. The executive committee consisting of the Dean's of OGS, SOE, and A&S as well as the Provost. The administration (Director, Associate Director, and APC) will work to implement any changes that the executive committee recommended. In addition, the management team which consists of faculty members

involved in the NSME are able to make suggestions about the curriculum or administration. The Director and Associate Director's were appointed by the executive committee and serve a 2-year term that is available for renewal based on management and executive committee suggestions. We currently do not have any external advisory board as we are a relatively small program. Currently, any changes made to the program fall under the administrations responsibilities but will be given approval by the executive committee.

Proposed NSME Budget in Future:

The proposed additional NSME budget needed to grow the program is summarized below. This involves increasing budget to resume outreach events, increase recruitment events, create a dedicated seminar, offer financial support for 1 year for incoming Ph.D students, budget for TA positions to assist in lab based courses, funding salary summer budget to cover lab during some summer needed to create online program. I have proposed a similar budget to the Provost to cover a TA and summer month salary but no allocations have been made. With the reduction in financial support from SOE the NSME is currently using all its reserves to cover expenses in 2022-2023, and according to UNM admin that will be depleted during the 2023-2024. Therefore, after 2024 school year we will not have the budget needed to sustain the program. The budget below is the additional resources needed to grow the program and include the above highlighted features into the program. One of the items is increased salary allocation to the administration as currently the APC is 0.5FTE and the Director and AD get approximately 0.4 months per year.

Description	Basis	Estimated Additional Cost per year
Director extended salary Associate Director salary	1 Summer Month in addition to SAC 0.5 Summer Month in addition to SAC	$12,000 not including Fringe $ 6,500 not including Fringe
APC Salary	1 FTE instead of 0.5 FTE	$26,500 not including Fringe
Graduate Assistants (RA)	3 RA Positions for a year	$92,334
Teaching Assistant (TA)	1 TA Position at 0.5 FTE (1 semester)	$15,388
Summer Instructor Salary	Cover 1 Month 1.0 FTE summer (online course)	$11,140
Seminar	Cover food, travel, accommodations (8 out of state speakers)	$12,000
Outreach and Recruitment	(Travel, science kits, Retreat, etc…)	$10,000
Total		**$185,862 annually**

Justification for additional budget request:

Administration salary: Currently Director Nathan Jackson gets $5,000 in SAC and Associate Director Susan Atlas gets $2,500 in SAC. These amounts are considerably lower than other interdisciplinary programs and $5k covers less than 0.5 months for Director and less than 0.25 months for AD per year. The amount of work required by the administration team to maintain the program far exceeds the amount of time they are paid. In the past APR the former Director (Prof. Datye) proposed a 0.5 FTE for the Director over the 9-month year or 4.5 months and 1 additional month in the summer they also requested a SAC for faculty involved in teaching core classes. We feel that providing the director with 1 summer month and the current SAC along with 0.5 summer months for AD and current SAC is a fair compromise.

Office Administration: Currently the APC is being split between BME and NSME so we only have an administrative at 0.5 FTE. However, considering the APC should be responsible for Budget, advising, day to day operations, and outreach events, as the program increases enrollment this will be a full-time job thus, we would like to raise this to 1.0 FTE.

Research Assistant Positions: The NSME would like to offer 3 year round RA positions to incoming Ph.D students or 6 half year RA positions depending on number of incoming Ph.D students to help support them during their first year. Often times students get accepted into multiple universities or different departments and in order to compete with top tier universities we would like to essentially offer students a 1-year scholarship. Recruitment and retention within the program are high. One of the barriers to attracting the best and most qualified students into the program is supporting students who enter into the program in their first year. Early on (2007-2012) students in NSME were completely supported by the fellowships, but now we require funds to help recruit students.

Teaching Assistant Position: Similar to the RA the TA is an opportunity to help support students, NSME 519 has a lab component which needs a TA and currently only 0.25 FTE is covered by ME department, we would like to get a TA to cover the other 0.25 FTE as well as summer months to cover the online version of the course. This will be used to support students in the 2nd or 3rd year after they have taken the course and to support students whose advisor might have lost external funding and can no longer support students through an RA.

Office/travel/recruitment/seminar Budget: Our operating budget includes the cost of student recruitment, one trip per year for attending a national meeting related to the Nanoscience education and outreach activities, funds to support an annual retreat and outreach events which require kits and expenses to develop short courses and demonstrations. In addition we would like to have our own seminar series where we would have approximately 8 out of state speakers and 6-8 in state speakers. The out of state speakers require travel, accommodations, food, and food and refreshments for each seminar for attendees, which costs on average $1500 per speaker. In addition, we would like to bring back the Nano Café monthly talks at the faculty club as it was a way to have students practice giving open talks on their research and provide networking to students.

Criterion 9. Facilities

9A: Current Space:

Currently, NSME program shares an office with the BME interdisciplinary program and the Center for Biomedical Engineering. The office consists of three offices, a reception desk, and a small conference room. The APC has one office, and the NSME Director has an office, and the Director of the Bioengineering Center also has the other office. The NSME Director did not have an office until Jan 2023 when the former director of BME left and the NSME director took over the office leaving the current BME director without an office. NSME does not have any individual classrooms, but UNM provides classrooms around campus or south campus (CHTM) that are used for teaching. We don't have any laboratories as these are assigned to departments, so our faculty have laboratories in their department. Currently we can meet our academic requirements as the program relies on individual faculty to provide research facilities for the students. The Director has helped faculty to obtain research equipment through DURIP's, MRI, and internal funding sources. For gatherings or meetings involving students and faculty such as orientation we currently rely on booking facilities with various departments, but this has not been a major issue to date.

The NSME has helped researchers bring in various equipment including computing clusters (NANO and GIBBS) housed in Center for Advanced Research Computing (CARC). Other equipment such as Dual Beam Quanta 3D focused ion beam and field emission gun SEM and new XRD. In addition, the director has been involved in getting various equipment for the microsystems for the cleanroom (see below).

In the last APR in 2012 the reviewers recommended that NMSE should have a common space home to promote interactions and collaborations. We have a common space home now that we share with BME program and is currently serving our needs. However, if we were to increase enrollment, we may need a larger facility that has an open-door policy as currently the office area is locked, and students need to setup appointments to discuss any issues they have.

9B: Future Space Needs*:*

As stated above currently the facilities are adequate for our needs, but if we increase enrollment then we would likely need to have more of an open-door policy which would require us to have a larger office space and maybe a receptionist that could be shared between BME and NSME. The director will continue to help support infrastructure and equipment proposals if they can help students in their research and for education equipment. The Director has recently participated in obtaining several equipment to help in the labs for NSME 519 (XeF_2 etcher, HF Vapor Etcher, Surface profilometer, 4 pt probe tester, mechanical tensile compression tester, and maskless aligner tool).

Conclusion. Strategic Planning

Discuss the unit's strategic planning efforts going forward to improve, strengthen, and/or sustain the quality of its degree programs (if applicable, differentiate between undergraduate and graduate). Address all criterion, including but not limited to: student learning outcomes, curriculum, assessment practices, recruitment, retention, graduation, success of students/faculty, research/scholarly activities, resource allocation, and facility improvement.

Overall the NSME program has been in existence for 15 years, and in the last 10 years we have graduated 56 Ph.D students and 61 M.S degrees. However, recently we have seen more Ph.D students and less MS students. The students who have graduated have gone on to have successful careers in academia, industry, national laboratories, and national organizations (FDA and US Patent Office). Over the past 9 years the program has been maintained through revenue received from three funding sources (A&S, SOE, and Provost) as well as course fees and differential tuition. The NSME program has had three different Directors and three different administration staff members in the 15 years and the new APC started in 2021 and the new Director started in August 2022. The NSME program is a relatively unique program even to UNM but it is one of three interdisciplinary programs associated with SOE (OSE, BME, and NSME). The three current directors of these programs are trying to setup monthly meetings to discuss methods of improving the programs and working with upper administration at UNM.

The current Director (Nathan Jackson) sees a lot of promise for the NSME program and ultimately wants the program to be one of the elite Nanoscience and Microsystems programs in the country, one that other universities APR look to for comparison. However, to accomplish this the new Director has numerous changes that he would like to implement, some in near future while others will be for the long-haul. <u>The overall objectives for the NSME program are to 1) Enhance Academic Excellence (top priority) and 2) Increase reputation and enrollment</u>. Below is a summary of future plans for the NSME programs which will allow us to accomplish these objectives, which I we would appreciate the reviewer's feedback.

1. **Curriculum and SLO:** Overall the Curriculum courses are similar to other nanoscience departments and programs at other universities, but our program combines nanoscience and microsystems and currently only 1 microsystem course is offered, but there are microsystem courses offered in other departments, so we need to get these cross listed to increase awareness for our students. In addition, we could create new microsystem courses that appeal to our student's interest, the Director has proposed a new BioMEMS course as well as a microelectronics and microsystem packaging course. Overall we want our students to have a diverse knowledge and skills when they graduate which will add value to their future employer and increase job readiness. We are also looking into whether we should require more technical electives or allow students to continue to substitute research problems courses for their technical electives, as there is value in both options.

2. **Assessment of Program and Courses:** The assessment of the program is currently performed by assessing the students during their dissertation or thesis defense. This works for PhD students but many of our MS students choose the coursework option and then never get assessed. Therefore, we will start assessing MS students by GPA in the core classes as well as through their overall GPA.

3. **Online MS Option:** The Director is interested in creating an online MS option to increase enrollment and to attract students who reside in other parts of the country. Several Universities have online engineering degrees for BS or MS students and we are looking at their curriculum. The challenge is in 1) how to handle lab-based courses and 2) resources to cover instructors' salary to teach the online courses. Currently our thoughts for the lab-based course is to have the students come out for 1-2 weeks in the summer to take a 1 credit lab course, but again we need money to cover instructor or TA salary. The advantage of an online degree is 1) increase enrollment leading to increased reputation across the country and 2) higher differential tuition which will increase our revenue to help support instructor salary.

4. **Increase Enrollment and Retention:** In order to grow the program we would like to increase enrollment but not at the expense of sacrificing academic excellence which is always our top priority. However, currently increasing enrollment has little advantages as it puts a larger burden on our instructors and administration as the only benefit is a slightly higher course fee and differential tuition revenue increase, but the extra revenue increase would not be enough to pay for TA or extra workload. Ultimately, we would like a consistent budget revenue from upper administration at UNM that increases with increasing enrollment.

5. **Create Shared-Credit Program with A&S Departments:** Another method that we are pursuing to increase enrollment and to retain high quality undergraduates to stay at UNM is to create a shared-credit program for undergraduate students in the A&S departments similar to what we have in the SOE. We have filed a request for this with the Chemistry department in 2022 and if it is successful, it will give us a good model to approach other departments in A&S such as physics and biology.

6. **Increase Outreach:** NSME program was always very active in outreach events for K-12 students and undergraduates. As well we often had networking events such as Nano Café which allowed NSME students and faculty to give short presentations on their research to other NSME students faculty often in a non-academic environment such as a café or faculty club. This allowed students

to network as well as get feedback on their research and provided soft skills (oral presentation skills), but this was cut due to budgets to cover food and refreshments.

7. **Increase Revenue:** Ultimately, to accomplish these goals we need to increase our revenue, and the last two years have resulted in significant pay cuts with SOE no longer contributing to our program or other interdisciplinary programs. We (NSME and other interdisciplinary programs OSE and BME) plan to meet with the new SOE Dean to discuss options when she arrives in April 2023. In addition, the NSME director submitted a proposal request to increase the budget from the Provost by ~$58k per year to help cover costs to develop an online MS program that would pay an instructor during the summer as well as fund 1 RA and 1 TA for a semester. Ultimately to accomplish all these goals we need a much higher revenue as illustrated in Criterion 8 (~$190k), but the NSME administration will continue to work to improve the program and work within the budget provided.

8. **Faculty:** NSME has a large number of faculty from a wide range of schools and departments. Most of the faculty only participate by advising students. We would like to get faculty more involved in the program (teaching technical electives, participating in qualifying exams and defense exams, as well as participation in retreats and providing feedback to administration on the program). However, faculty have responsibilities in their own department and often do not get credit from their Chairs for the work they do in NSME or other interdisciplinary programs. We would like upper admin to give credit and recognize the work faculty do in the program, in regard to their service responsibilities in the departments. In addition, the Director would like to be involved in the hiring process for departments looking to hire faculty that fit in the nanoscience and microsystem area as he can provide valuable feedback to search committees. Also, the NSME administration needs to meet with new faculty to talk about the program to make them aware of it. Since the director has taken over in August 2022, I was approached by several junior faculty that new nothing about the NSME or various centers, so upper admin at UNM and chairs do not do a good job of promoting these programs or at least mentioning them. Therefore, we need to work with chairs and admins to help promote the programs, but often times this is not performed because then we are taking students away from their department, so we are often seen as a burden rather than what is best for the students.

Issues and Concerns Raised by Administration Team

NSME is a joint program between the School of Arts and Sciences and the School of Engineering with extensive ties to the School of Management and the School of Medicine. The NSME program does not have any faculty lines, so all faculty come from the participating departments. At present the output from the NSME program (students graduated, credit hours, student awards) does not get counted within either SOE or A&S, this is a major concern to the Deans of SOE and A&S as this takes away from schools and significantly affects their national ranking. When the NSME program was proposed, it was recognized that a certain amount of double counting would be needed. For example, since NSME degrees are not reported to the ASEE or to the U.S. News and World Report, we are undercounting the performance of each of these colleges. With small departments, when a significant number of students advised reside in the NSME program, it could lead to serious deficiencies in reporting the productivity and performance of the individual departments and colleges. We still need to develop methods to overcome this, if done at the institutional level, the actual numbers reported to the outside world would be fair and auditable and not based on specific counting schemes. We feel that setting up a transparent counting method will allow the participating departments and colleges to get full credit for the role played by their faculty in this interdisciplinary program. This will help address the concern that some departments see the NSME and

other interdisciplinary programs as a threat rather than an asset. Discussions with Department chairs and regular communication may also help alleviate this concern. We would like to add that the School of Engineering adds NSME graduates in their annual convocation lists and NSME students get to participate in the School of Engineering convocation where they can be hooded by the faculty who advised them. Since the A&S does not hold one major convocation, this is not an issue, and we would like to encourage other departments in A&S when they hold their convocation to also include students that were advised by their faculty but got degrees in the NSME program.

High Priority Issues

As the only interdisciplinary program on campus that spans multiple departments across four different colleges, the NSME program needs to find a place in the UNM administrative and academic structure that ensures sustainability of the program. This includes securing financial support in the form of a recurring and consistent budget. Also, currently there is no motivation for wanting to increase enrollment as the budget remains the same but as we add students we put a larger burden on the APC, Director, and instructors teaching the courses as there are no TA's. The NSME administration feels the budget received by the Provost and Deans should be based on number of enrollment that way we increase our budget if we increase enrollment providing some incentive for wanting the program to grow.

Near Term Tasks

- Improve our web presence to be able to attract high quality graduate students.
- Build and improve our social media presence
- Increase recruitment efforts at UNM
- Increase the number of faculty participating in teaching NSME core and elective classes so we have a backup as faculty go on sabbatical.
- Add technical elective courses associated with microsystems
- Enhance the interaction with the participating departments in the School of Engineering and Arts and Sciences to coordinate graduate recruiting and outreach activities.
- Design a proper course sequence and list of technical electives for students with specific thrust interest in nano-bio, microsystems/semiconductors, or materials.
- Increase outreach events back to pre-COVID times.
- Obtain a consistent source of budget and start getting money from SOE to levels pre-COVID.
- Get shared-credit program started with Chemistry department

Longer Term Tasks

- Work with other units across campus to extend the scope of the NSMS PSM (Professional Science Masters) program and try and promote this program.
- Increase budgets from UNM to provide financial support for administration, students, outreach, and recruitment events.
- Obtain teaching and/or graduate fellowships to attract and support excellent incoming graduate students.
- Increase the educational and research profile of the program nationally by having students list NSME on their affiliations when writing papers or presenting at conferences.
- Participate in the hiring of new faculty in affiliated departments and include them in the collective activities of the NSME program.
- Develop an online MS option (to increase enrollment on a national level).
- Get shared credit program option for other departments in A&S (ie. Biology and Physics)
- Work with ESS to get URE positions.

- Write Educational Graduate Grants to help cover new course development and support students through fellowships

Questions to the Committee:
The NSME program has identified specific issues and questions that are being posed to the review team. Each question is annotated with a brief explanation, further details will be found in the relevant sections of this document.
(1) Budgetary Issues
How are interdisciplinary programs at your institutions supported? What is a reasonable level of support for a graduate program that enrolls over 60 graduate students? What other sources of funding (external and internal) should we target?

The NSME program currently has a graduate student enrollment that that is comparable in size to some departments within the SOE. What level of institutional support is needed in terms of administrative staff, office space, day-to-day operations and student support (teaching and graduate assistantships, e.g.) to ensure that the program will continue to prosper and achieve the goals set forth in this report. Unlike graduate students in many of the science and engineering departments, students in the NSME program currently do not have access to teaching assistantships in their first year. Support of incoming students is key to attracting the most qualified graduate students to the program. Most federal training grants are intended to be seed grants that require institutional support after the grant has ended. Our current budget is negative due to the $0 contribution from SOE over the past 2 years due to COVID budget cutbacks, we are eating away at our reserves and accordingly as of 2024 we will be out of reserves so cutbacks are needed or additional funds are needed to maintain current program, but the director would like to grow the program which requires additional funding as demonstrated in Criterion 8.

(2) Governance & Administration
What are effective models for the management of interdisciplinary programs? What are the advantages/disadvantages of centralized management models, e.g. under the Office of the Provost vs. collaborative models distributed across the Deans of two or more colleges? What are the budgetary consequences of adopting one model over the other?

The NSME program is the only program on campus that spans many different departments over the College of Arts and Sciences and the School of Engineering, with involvement from both the School of Medicine and the Anderson School of Management. As a result, NSME is not the primary concern (financial and academic) of any one of these Colleges. If NSME is to be sustained and to prosper, a proper administrative structure needs to be established. The reporting structure for the NSME program has evolved, but currently we report to OGS, A&S, SOE and provost. Originally, we reported to an executive committee consisting of 5 members – Deans of Engineering, Arts and Sciences, Graduate studies and Business and the VP for Research (because the program originated from a research grant and represents integration of research and education). The previous Dean of Engineering preferred a multiple dean model which was implemented nearly 10 years ago, but now other programs such as OSE APR reviewers have determined that 1 Dean model might be better. What is missing in this picture is the connection to funding. The program cannot be funded by one Dean, and thus far the matching support came from A&S and Engineering. Is this the best way to move forward? Or should the program be under one roof, such as the Dean of Graduate studies and a budget line created for this program? The problem is that in a performance-based budgeting system neither Dean gets credit for the credit hours or students graduated, since the NSME is a degree that exists on its own, i.e. it is neither in Engineering or in A&S. And finally,

how can NSME play a role in the hiring plans and hiring process to attract young faculty into departments that will ensure the long-term sustainability of the program?

(3) Faculty Issues

What steps need to be taken to ensure the continued participation of faculty in the NSME program? What mechanisms can be put in place to allow faculty to get credit for teaching NSME courses. Can the management structure also provide growth opportunities? How, for example, can the NSME program be included in the process of hiring tenure track faculty in the participating departments?

The NSME program was developed on the premise that the core courses are ones that faculty have taught or wanted to teach as electives. Hence, while teaching what interests them, they can also teach a NSME core course. However, the issue arises if faculty leave or are not able to teach the course then do we make a new course or try and find someone that could teach the course but might not be as interested in the topic? The NSME class is cross listed with the primary department where the instructors come from, so students taking it as an elective sign up for that section, but this reduces the amount of money received by NSME for course fees. During the program planning, the Deans of A&S and Engineering agreed that this should not result in an overload for the faculty member. In practice some department chairs took the position that teaching such a class pulls away a faculty member from the core mission of the department, and there have been cases when a course had to be dropped for this reason (also the BME Director had to recently step down as his Chair demanded he focus on his department duties as opposed to the interdisciplinary program duties. Therefore, faculty involved in NSME need to be given some credit for their work effort, such as participating in qualifying exams in NSME, as currently faculty are required to participate in their own department's activities and services, but if faculty participate in NSME that should count towards their work loads. We should have a policy in place to allow faculty to teach interdisciplinary courses to count towards their teaching load within their department. Currently there is nothing on paper and it is up to the Chairs of the department to allow or not allow this, which creates issues when trying to sustain a program and courses. We must overcome the perception that these classes outside the department won't count towards the workload, or towards tenure and promotion. Given the number of graduate students in the program, what mechanisms can be put into place to ensure that an interdisciplinary program such as NSME can participate in faculty hiring?

(4) Curriculum Issues

Is the current core curriculum appropriate? Should we have a flexible core to accommodate the breadth of student from the physical and biological science as well as microsystems while preserving the essential features of the NSME?

How appropriate is the core curriculum for the NSME graduate student population? Is the material covered adequate, or should some of the topics covered be altered for instance some more courses on Microsystems? Should there be a "soft core" with a choice of three out of five core courses? In the last few years, the number of students in the NSME interested in nano/biosystems has increased. How should the curriculum accommodate this? Should new areas of concentration (such as energy) be added? What is the value of the concept of a concentration, and should we offer concentrations, or are there more effective approaches? Should we require more or less courses and technical courses? Is allowing students to take problems or research hours instead of technical electives best for the student?

(5) Future Directions

How should the NSME program build on the success of the Professional Science Master Program and promote this to bring this program back? What can the NSME program do to incorporate the vision of the innovation Academy to fundamentally transform graduate education?

(6) Online MS Option

Is the idea of an Online MS option in NSME a good idea? How can we implement lab-based courses into an online program?

Appendices

Appendix C: Three-day Site Visit Itinerary

Day One: April 19, 2023

Time	Activity	Who is responsible	Location
6:30 to 7:45 a.m.	Breakfast at hotel – Unit will pick up team members	Nathan Jackson	
8:15 a.m. to 9:00 a.m.	Review Team Orientation Meeting Director Assessment & APR; APR Specialist, unit's chair, DA, (***optional*** - Self-Study Report committee)	Unit/ APR Specialist	
9:00 a.m. to 10:45 am	Program Overview/ History/ Faculty/Research/ Students/Outcome Assessments Future Plans/Issues and Concerns	Nathan Jackson Susan Atlas	**NSME Conference Room CEC 2041**
11:00 a.m. to 11:45 p.m.	MTTC Tour	Nathan Jackson	**MTTC**
11:45 am. to 12:30 pm	CHTM Tour	Nathan Jackson	**CHTM**
12:30 pm to 1:00pm	Payman Zarkesh-Ha, Director of CHTM	Nathan Jackson	**CHTM Office**
1:15 p.m. to 2:15 p.m	Lunch (Nathan Jackson, Yvone' Nelson, Lok-kun Tsui)	Nathan Jackson	
2:20 p.m. 5:00 pm	NSME Faculty Sessions: 2:20-2:40 pm: Andrew Shreve CBE 2:40-3:00 pm: Matthew Lakin CS 3:00- 3:30pm: ? 3:30- 4:00 pm: Jeremy Edwards, Chair of Chemistry 4:00-4:20 pm: Xiang Xue, Biochemistry Molecular Biology (zoom) 4:20- 4:40pm: ? 4:40- 5:00 pm: Marek Osinski, ECE	Nathan Jackson	**CEC 2041**
5:00 p.m. to 9:00 p.m.	Working dinner (Nathan Jackson)	Nathan Jackson	

Day Two: April 20, 2023

Time	Activity	Who is responsible	Location
6:30 to 7:45 a.m.	Breakfast at hotel – Unit will pick up team members	Nathan Jackson	
8:00 a.m. to 9:00 a.m.	Advisement/Outreach/Recruitment/	Yvone' Nelson Nathan Jackson	CEC 2041
9:00 a.m. to 10:00 a.m.	Sang Han, Chair of Chemical and Biological Engineering	Nathan Jackson	Farris CBE
10:00 a.m. to 11:00 a.m. (mandatory meeting)	Meeting College/School Leadership CAS – Interim Dean Janie Chermak CAS – Associate Dean Sharon Nepstad SOE – Donna Riley SOE – Associate Dean Charles Fleddermann	APR Specialist	**Ortega Hall CAS Dean's Office**
11:00 a.m. to 12:00 p.m.		Unit	
12:00 p.m. to 1:00 p.m.	Lunch Meeting with NSME Students (Sudha Ananthakrishnan)	Unit	
1:00 p.m. to 2:00 p.m. (mandatory meeting)	Meeting with Institutional Leadership Provost James Holloway Associate Provost Pamela Cheek OVPR representative	APR Specialist	**Scholes Hall Academic Affairs room 246**
2:30 p.m. to 3:00 p.m.	Heather Canavan, Faculty CBE	Unit	CEC 2041
3:00p.m. to 3:30 p.m.	Yu-Lin Shen, Chair of Mechanical Engineering	CEC 2041	CEC 2041
3:30 pm to 4: 00 pm	Christina Salas, Director of BME Program & HSC Faculty	CEC 2041	CEC 2041
4:00 p.m. to 5 p.m.	CARC tour (Matthew Fricke)	Matthew Fricke	CARC

5:00 p.m. to 9:00 p.m.	Working dinner (Sang Han)	Sang Han	

Day Three: April 21, 2023

Time	**Activity**	**Who is responsible**	**Location**
6:30 to 7:45 a.m.	Breakfast at hotel – Unit will pick up team members	Nathan Jackson	
Morning 8:00 a.m. to 10:45 a.m.	Review Team Meeting to prepare presentation	Unit	
11:00 a.m. – 12:00 p.m.	Exit meeting attended by: Review Team, Provost, Associate Provost for Curriculum, Dean of Graduate Studies or designee, as applicable; College/School Dean, Associate Dean(s), Director of Assessment & APR, Unit's chair, Chair of the Self-Study Report committee, APR Specialist	Unit/ APR Specialist	**Scholes Hall Robert's Room**
1:00 p.m.	Reviewers depart Albuquerque	Unit	

Appendix D: Faculty Credentials

Name of Department/Academic Program(s): Nanoscience and Microsystems Engineering Program

Full First and Last Name	**Faculty Appointment** Continuing • Lecturer (LT) • Probationary/Tenure Track - Instructor (TTI) or Asst. Prof. (TTAP) • Tenured - Assoc. Prof. (TAP), Prof. (TP), or Dist. Prof. (TDP) • Prof. of Practice (PP) Temporary • Adjunct (AD) • Term Teacher (TMT) • Visitor (VR) • Research Faculty (RF)	**Institution(s) Attended, Degrees Earned, and/or active Certificate(s)/Licensure(s)** (e.g., University of New Mexico—BS in Biology; University of Joe Dane—MS in Anthropology; John Doe University—PhD in Psychology; CPA License—2016-2018) **Only Terminal Degree is Necessary**	**Program Level(s)** (Please leave blank or provide "N/A" for each level(s) the faculty does not teach at least one course.)		**Faculty Credentials** • Faculty completed a terminal degree in the discipline/field (TDD); • Faculty completed a terminal degree in the discipline/field and have a record of research/scholarship in the discipline/field (TDDR); • Faculty completed a terminal degree outside of the discipline/field but earned 18+ graduate credit hours in the discipline/field (TDO); OR • Other (Explain)
1. Nathan Jackson	TTAP (Mechanical Engineering)	Arizona State University PhD Bioengineering	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
2. Hien Pham	RF (Chemical and Biological Engineering)	University of New Mexico PhD, Chemical Engineering	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
3. Abhaya Datye	TP (Chemical and Biological Engineering)	University of Michigan Ph.D, Chemical Engineering	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
4. Andrew Shreve	TP (Chemical and Biological Engineering)	Cornell University Ph.D Physical Chemistry	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
5. Nick Carroll	TTAP (Chemical and Biological Engineering	University of New Mexico Ph.D, Chemical Engineering	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
6. David Dunlap	TP (Physics & Astronomy)	University of Rochester Ph.D (Physcis)	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
7. Lok-Kun Tsui	RF (Chemical and Biological Engineering)	University of Virginia, PhD, Materials Science and Engineering	Undergraduate	X	TDDR
			Graduate	X	
			Doctoral	X	
8. William Gannon	RF (Biology)	University of New Mexico, PhD Biology	Undergraduate	X	TDO
			Graduate	X	
			Doctoral	X	

Appendix E: Peer Comparison

PEER Programs/ INSTITUTIONS (2022)	Total Enrollment	Unit Undergraduate Degrees/Certificates Offered	Unit Undergraduate Student Enrollment	Unit Graduate Degrees/Certificates Offered	Unit Graduate Student Enrollment	Total # of Unit Faculty
NSME UNM	39	NA	NA	• MS • PhD	• 6-MS • 33-PhD	92
Mechanical Engineering UNM	598	• BS • Microsystems Concentration	499	• BS • MS • PhD	• 76-MS • 23-PhD	16
Chemical and Biological Engineering UNM	190	• BS	155	• BS • MS • PhD	• 17-MS • 18-PhD	21
Electrical and Computing Engineering UNM	622	• BS	359	• BS • MS • PhD	• 155-MS • 108-PhD	33
Biomedical Engineering Program UNM	35	NA	NA	• MS • PhD	• 16-MS • 19-PhD	NA
Optical Science Engineering Program	54	NA	NA	• MS • PhD	• 13-MS • 41-PhD	NA

Appendix F: Assessment Plan (example Ph.D)

Student Learning Outcomes (SLOs) *For each row in the table, provide a SLO. If needed, add more rows. A SLO may be targeted by or aligned with more than one program goal. If a program awards more than one degree (i.e., B.S., M.A. etc.), the SLOs for graduate and undergraduate must be different. Graduate degree SLOs must be different (Master ≠ Doctorate). For additional guidance on SLOs, click here.*	**Program Goal #** *Please list the Program Goal(s) that the SLOs are aligned under. Use the numbering system (1,2,3..) assigned above.*	**UNM Student Learning Goals** *Check as appropriate: K=Knowledge; S=Skills; R=Responsibility*			**Assessment Measures** *Provide a description of the assessment instrument used to measure the SLO. For additional guidance on assessment measures, click here.*	**Performance Benchmark** *What is the program's benchmark (quantitative goal/criteria of success for each given assessment measure)? State the program's "criteria for success" or performance benchmark target for successfully meeting the SLO (i.e., At least 70% of the students will pass the assessment with a score of 70 or higher.)*	**Student Population(s)** *Describe the sampled population, including the total number of students and classes assessed. See note below.*
Knowledge of Nanoscience and Microsystems Fundamentals	1	K ☒	S ☐	R ☐	PhD Rubric	An average of 3 and above is considered acceptable	Graduating PhD students during the academic year
Ability to conduct original and independent research	2	K ☐	S ☒	R ☒	PhD Rubric	An average of 3 and above is considered acceptable	Graduating PhD students during the academic year
Ability to critically review literature related to specialized field	3	K ☐	S ☒	R ☒	PhD Rubric	An average of 3 and above is considered acceptable	Graduating PhD students during the academic year
Ability to communicate effectively	4	K ☐	S ☒	R ☒	PhD Rubric	An average of 3 and above is considered acceptable	Graduating PhD students during the academic year
Depth of knowledge of specialized field	5	K ☒	S ☒	R ☐	PhD Rubric	An average of 3 and above is considered acceptable	Graduating PhD students during the academic year

Assessment Report for 2022 school year.

SLOs (copy and paste from PLAN above) *Copy and paste your SLOs from your entries in the PLAN above that were **measured during this year**.*	**Student Population** *Describe the sampled population, including the total number of students and classes assessed.*	**Results*** *State whether the performance benchmark was met, not met, or exceeded AND the total number of students assessed (i.e., Exceeded, 95 out of 111 (86%) students)*
Knowledge of Nanoscience and Microsystems Fundamentals	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.2
Ability to conduct original and independent research	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.5
Ability to critically review literature related to specialized field	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.3
Ability to communicate effectively	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.1
Depth of knowledge of specialized field	Graduating PhD Students during the 20-21 academic year	6 students were assessed out of 6 (100%), average rating 3.2

Example of Ph.D Assessment Rubric given in Appendix I:

Appendix H: Mid-Cycle Check-In Form:

OFFICE OF ACADEMIC AFFAIRS

APR Mid-Cycle Check-In

Unit Name: Nanoscience and Microsystems Engineering Program
Previous APR Site-Visit Dates: 2012
Next Scheduled APR: April 2023

Unit Chair: Updates to Recommendations

Address all APR-related recommendations incorporated in the Unit Response and Action Plan documents, ***adding rows as necessary****. New initiatives can be included and discussed, even if they were not included in the Unit Response or Action Plan.*

Reviewer Recommendation or Finding	Action Taken since Review	Future Action
UNM upper administration should recognize, and more importantly, communicate, the added value of interdisciplinary endeavors to its stakeholders	The administration continued its support of NSME and recognizes the value of interdisciplinary education. The school of engineering recognizes all interdisciplinary degrees in the spring and fall convocations, providing a more visible presence to students and parents attending these events.	
UNM upper administration should provide clear governance policies and an administrative home for NSMS	The governance structure of NSME was revised to provide clear lines of reporting.	We are in discussions on determining if we could move under OGS along with OSE, as there is benefits to being under only 1 school/dean.
UNM upper admin should provide clear policies regarding resource allocation, credit assignment, workload expectations and faculty evaluations to those involved in NSME.	NSME now cross lists its courses with departments so that faculty can get credit for teaching the courses. Policies with credit assignment and workload and faculty evaluations are governed by the departments	I would like to work with departments to also give credit for faculty who participate in other NSME services like qualifying exam etc..
UNM upper administration must ensure a more predictable revenue steam to NSMS to support its program administration, student recruitment, publicity,	After 2012 we started receiving funding resources from SOE and A&S and later from the Provost office, but these are not predictable. The SOE did start giving us differential tuition.	I would like to only receive funds from one source and make sure it is predictable and based on enrollment, so that we get higher budget if we have more students enrolled. Right now, we have no

seminars/colloquia, grant proposal development activities.		support for student assistantships which needs to change.
NSMS should craft a mission statement, strategic plan, vision statement and an estimate/justification of its program costs.	This was on the list of things to do but was not accomplished right away.	This could be be something we put together in the future.
NSMS should build on its strengths to proactively support economic development initiatives of UNM	NSME continues to support economic development by providing opportunities for graduate education for students who otherwise would not come to UNM since majors such as materials science, or nanotechnology are not offered.	We will obtain feedback from industry on students who graduated from NSME and we will try to work more closely with industry and start promoting the PSM area.
UNM should provide a physical home for NSMS (minimum, a common space) to encourage collegiality, promote interactions, maintain sense of identity	UNM met the minimum by providing us an office that we share with BME and Center for Bioengineering. However, doors are usually locked (no open-door policy) so little effort to encourage collaborations.	If we had more funding we could hire front desk receptionist to allow an open door policy. Also, currently there is only 1 office for BME or NSME Director not both.

Unit Chair: Assessment Reflection

Consider the unit's assessment practices since the last APR. Please provide a small narrative reflecting on assessment impact, strengths, concerns, or obstacles that exist within the unit, focusing on those areas that would be well-served by leadership feedback and/or highlighted to reviewers at the unit's next APR.

Unit Chair: Review and Confirmation

Comments:

The items provided in the Mid-Cycle Check in align with information provided in the previous Unit Response Report and Action Plan. **YES** ☐ **NO** ☐ **PARTIALLY**

Print Name _____ Signature _____ Date (MM/DD/YYYY) _____

Dean/Associate Dean: Dean's Office Review and Approval SOE

Comments/Feedback:

Print Name	Signature	Date (MM/DD/YYYY)

Dean/Associate Dean: Dean's Office Review and Approval A&S

Comments/Feedback:

Print Name	Signature	Date (MM/DD/YYYY)

Dean/Associate Dean: Dean's Office Review and Approval OGS

Comments/Feedback:

Print Name	Signature	Date (MM/DD/YYYY)

Provost/Associate Provost: Office of the Provost Review and Approval

Comments/Feedback:

Print Name	Signature	Date (MM/DD/YYYY)

Appendix I: Assessment Rubric for Ph.D and M.S Students

NSME PhD Outcomes Assessment Rubric

To be completed by committee chair in consultation with exam committee.

Student Name: _____ Degree program/concentration: NSME

Date: _____

Outcome	Unacceptable (1)	Marginal (2)	Acceptable (3)	Exceptional (4)	Rating
1. Knowledge of NSME fundamentals appropriate for discipline and specialization	No evidence of PhD-level fundamental knowledge in NSME.	Rudimentary knowledge of NSME exhibited in written document and oral presentation.	Knowledge of NSME fundamentals evident in written and oral presentation.	Demonstrates mastery of appropriate fundamentals of NSME.	/4
2. Depth of knowledge in specialization	Only rudimentary knowledge in specialization.	Some knowledge of specialization demonstrated.	Demonstrates appropriate level of knowledge in specialization.	Demonstrates knowledge of specialization comparable to experienced practitioner.	/4
3. Ability to conduct original and independent research	No evidence of planning and execution of research program.	Some useful research results with some evidence of original work.	Carried out good research program, achieved useful and novel results.	Excellent planning and execution of research program. Excellent results.	/4
4. Ability to perform critical review of literature in NSME and area of specialization	Rudimentary literature review.	Some review of the literature, but little critical evaluation.	Comprehensive review of literature with evidence of critical thinking about further needs for research in this area.	Extensive review of the literature with critical evaluation comparable to a review article in literature.	/4
5. Able to communicate effectively	Dissertation poorly written. Oral exam not well planned or presented. Unable to answer questions.	Dissertation mostly clearly written. Presented main points clearly. Able to answer some but not all of the questions posed by committee.	Well written and well organized dissertation. Well organized and clear presentation. Good ability to answer questions.	Excellent job of writing and organizing dissertation. Well organized talk. Able to respond to questions and facilitate further discussion of results.	/4
Overall Assessment					/20

NSME Masters Degree Outcomes Assessment Rubric

To be completed by committee chair in consultation with exam committee.

Student: _____ Degree program/concentration:_____

Date:_____

Outcome	Unacceptable (1)	Marginal (2)	Acceptable (3)	Exceptional (4)	Rating
1) Knowledge of NSMS fundamentals appropriate for discipline and specialization	No evidence of Masters level fundamental knowledge of NSMS.	Rudimentary knowledge of NSMS exhibited in written document and/or oral presentation.	Knowledge of fundamentals of NSMS evident in written and/or oral presentation.	Demonstrates mastery of appropriate fundamentals of NSMS for the discipline.	
2) Ability to communicate effectively in oral and/or written form	Document poorly written; and/or poorly organized oral presentation.	Document mostly clearly written. Presented main points clearly; and/or oral presentation mostly clear and well-organized.	Well written and well organized document; and/or good job of organizing talk and well presented oral report.	Excellent job of writing and organizing document and discussion of results; and/or excellent job of organizing and presenting oral report.	
3) Ability to critically assess or apply information in NSMS and specialization	Rudimentary review or application of disciplinary information.	Some review or application of disciplinary information, but little critical evaluation.	Comprehensive review or application of disciplinary information with evidence of critical thinking about further needs for research or study in this area.	Extensive review or application of disciplinary information with critical evaluation comparable to a review article in literature; or knowledge comparable to that of an experienced practitioner in NSMS.	
Overall Assessment	**Unacceptable (1)**	**Marginal (2)**	**Acceptable (3)**	**Exceptional (4)**	

Comments (use back if necessary):

Appendix J: Qualifying Exam Rubric

FACULTY NAME:	Student Performance (General Observations)			
Category	**Unacceptable (0)**	**Marginal (1)**	**Good (2)**	**Rating (0 – 2)**
Organization & Structure	No clear organization.	Some organization is present, but there are several significant gaps in the presentation.	Organized, with a small number of minor gaps.	
Timing	Significantly over or under the requested time for the presentation, with no justification.	Presentation is moderately over or under the requested time.	Presentation is slightly over or under the requested time.	
Oral Presentation	Confused speech, with poor use of technical English. Speaker is difficult to understand or even to hear properly.	Some significant flaws in use of technical English. Speech is somewhat awkward or some minor effort is required to understand the speaker.	Use of technical English is good, with only a few minor flaws. Speech is audible and understandable.	
Visual Effectiveness	Visual aids are illegible or not understandable without substantial effort. Visual aids make no contribution to the overall effectiveness of the presentation.	A minority of visual aids are clear and well described. Most visuals do not contribute to the effectiveness of the presentation.	Most visual aids clear and well described. Most contribute to the overall effectiveness of the presentation.	
			Total	
			Score **(Out of a Maximum of 8 PTS)**	

Category	**Unacceptable (1)**	**Marginal (2)**	**Good (3)**	**Excellent (4)**	**Rating (0 - 4)**
Critical Analysis of Research Paper	Insufficient depth. Inappropriate technical level. Missed the big picture – impact and significance of the paper	Understood some aspects of the paper, but the overall presentation lacked depth. Technical content was too low for a Ph.D. level analysis.	Most topics sufficiently described, but not enough emphasis on the most important points. Technical level is appropriate.	Demonstrates excellent understanding of the paper with emphasis placed on the most significant areas, at a high technical level.	
Ability to answer questions on the technical aspects of the paper. Background and preparation in the NSMS core subjects & in the fundamental science and engineering concepts.	Student was unable to answer questions	Student could answer some questions, but overall had difficulty answering in-depth technical questions	Student answered most technical questions adequately, but showed some deficiencies in a particular area	Student could answer most questions adequately to demonstrate a sound technical knowledge of the basic underlying principles	
Relevance and technical feasibility of proposed research	Proposed research has no apparent connection to the paper reviewed or research is not feasible	Research is loosely related to the paper. Not much thought given to how research can be accomplished	The proposed research covers similar ground as the paper, but does not lead to new directions. The necessary equipment or theoretical framework is well defined, but with some gaps.	Research proposal makes good use of the paper as a springboard to delve into new areas. The proposed research is both feasible and novel and the tools – experimental and theoretical are available.	
Novelty & Originality	Proposed research lacks novelty and originality. Research is a simple continuation of previous work.	Proposed research has some novel aspects, but these are poorly developed and without a clear design.	Research breaks new ground, demonstrates a clear understanding of the needs and goals.	Proposes original work that is well thought out and justified. The research problem is clearly stated..	
Research Plan	No appreciation for the timeline, how long it would take to do the research.	A reasonable timeline is presented, but the resources available (time and equipment) do not match what is needed.	A good deal of thought has been devoted to the conduct of the research, an experimental plan is proposed.	A well defined research plan, with clear milestones and deliverables. The work can definitely be accomplished within the scope of a Ph.D. dissertation.	
Technical discussion of the proposed work	Speaker evades answering any questions that were asked or cannot answer simple technical questions	Speaker has clear difficulties in handling most questions.	Speaker is able to address most questions with confidence.	Speaker is able to answer all questions clearly, effectively, and with confidence.	
				Total	
				Score **(out of a maximum 24 PTS)**	
			COMBINED OVERALL SCORE	**TOTAL Pg 2 + Pg 3** **(Out of a maximum 32 PTS)**	

The scoring of the exam is as follows <22 fail, 22-27 satisfactory and 28-32 excellent. If students are in the satisfactory area extra courses or suggestions to improve areas are given to the student in a conditional pass.

Appendix K: Course Syllabi for NSME Core Classes

I. NSME 510: Chemistry and Physics at the Nanoscale

Instructor: David Dunlap (Physics) and Andrew Shreve (CBE)

Cross listed as:
CBE 515 (Sec. 003); CBE 499 (Sec. 005); CHEM 567 (Sec. 002); CHEM 471 (Sec. 004); PHYS 581 (Sec. 005);
PHYS 480 (Sec. 001)

Time: Tuesday/Thursday, 4:30 to 5:45 PM, in-person or by Zoom

Prerequisites: Informal permission of instructor for students not in NSME, BME, CBE, PHYS or CHEM graduate or undergraduate programs.

Course Summary: This course will introduce students to basic theories and concepts in physics and chemistry that are needed to understand the behavior of matter at the nanoscale. A theme throughout the course will be properties and behavior that are encountered on the nanometer length scale (1 nanometer = 10^{-9} meters), whether descriptions arise from a bottom-up or top-down perspective. The behavior of nanoscale materials and the consequences of length scale in determining that behavior will be illustrated by discussion of specific chemical, physical and biological systems. General and basic concepts of physics and chemistry, including thermodynamics, quantum mechanics, band structure, light-matter interaction, and introductory statistical mechanics will be applied to the understanding of these systems.

Instruction Mode: This course will be delivered in a face-to-face, synchronous online, or fully online format, depending on section and student needs. A Zoom link for class meetings will be provided through the course site in the UNM Learn system. In-person and synchronous online class meetings are 4:30 to 5:45 on Tuesday and Thursday. The majority of instructional material will be delivered during these class meetings. Class meetings will also be recorded and posted allowing for fully online participation. Supplemental material and resources, including notes from the class meeting presentations, will also be available in the UNM Learn system. If possible, students are strongly encouraged to attend and participate in the class meetings as student questions and discussion will contribute to the overall instructional experience.

Textbook and Resources:

Instructors will provide resource material for the course. Some open source material that will be used or that may provide useful background information is found in the following texts and links. The DeVoe text and the two OpenStax texts are currently posted in the "Resources" folder of the course's Learn site, and additional resource material may be made available in that folder as the semester progresses.

H. DeVoe, *Thermodynamics and Chemistry* (2nd Edition, version 10). This text is a chemical thermodynamics book, also available for download at http://www2.chem.umd.edu/thermobook/downloads.htm. The copyright is owned by Professor DeVoe and usage is licensed under a Creative Commons Attribution 4.0 International License. This entire textbook provides useful background for our course, especially if you have not had prior courses covering concepts of classical equilibrium thermodynamics in chemical systems.

Open-source Biology textbook OpenStax *Biology 2e*, senior authors M.A. Clark, J. Choi and M. Douglas (download for free at https://openstax.org/details/books/biology-2e). The copyright of this text is owned by Rice University and usage is licensed under a Creative Commons Attribution 4.0 International License. Useful background material for this course is in Chapters 2, 3 and 5. Chapters 1 through 10 plus Chapters 14 through 17 provide a solid general introduction to Cell Biology for those interested in learning more, though this additional information is not needed for this course.

Open-source Modern Physics textbook *OpenStax Physics Volume 3*, senior authors S.J. Ling, J. Sanny and W. Moebs (download for free at https://openstax.org/details/books/university-physics-volume-3). The copyright of this text is owned by Rice University and usage is licensed under a Creative Commons Attribution 4.0 International License. Chapters 6 through 9 (especially Chapters 7 and 9) provide useful material for topics that will be covered in this course.

Students who plan to continue advanced graduate studies and research in topics covered in the course may also find some of the following texts, available for purchase, to be useful in their future work. Brief excerpts of some of these texts may be used for some topics in the course and will be provided as needed for instructional purposes.

K.A. Dill and S. Bromberg, *Molecular Driving Forces: Statistical Thermodynamics in Biology, Chemistry, Physics, and Nanoscience* (2nd edition).
D.A. McQuarrie and J.D. Simon, *Physical Chemistry: A Molecular Approach*. (Many other physical chemistry texts are also appropriate for coverage of the material we will discuss.)
N.W. Ashcroft and N.D. Mermin, *Solid State Physics*.
C. Kittel, *Introduction to Solid State Physics*.
R. Phillips, J. Kondev, J. Theriot, and H. Garcia, *Physical Biology of the Cell* (2nd edition).
S. Lindsay, *Introduction to Nanoscience*.
J.N. Israelachvili, *Intermolecular and Surface Forces.*

Computer Use and Software:

• Computer: Students are expected to have a computer available for use with an up-to-date operating system and be able to make use of software packages available through institutional licenses.

• Matlab: Students should have available an up-to-date installation of Matlab. Information on downloading and installing Matlab for UNM student use is found at http://it.unm.edu/download/. In addition, Matlab is available for use in many university computer labs.

• Microsoft Office, especially MS Word and Excel: Students must be able to read and manipulate files posted in Microsoft Office formats, generate a pdf file from a Microsoft Office file, and post a pdf file to learn.unm.edu. Students should also be familiar with using Excel for simple calculations.

• Other open source software packages may be used in assignments throughout the semester. Instructions for use of these packages will be provided as needed.

• Students must use the UNM Canvas system: Students are responsible for ensuring that their email address in the UNM system is a reliable method of contact as assignments and course announcements will be communicated through this system. In addition, course material such as lecture notes, lecture recordings, other instructional material, and supplemental material will be posted on this system.

Course topics (subject to change):*

The course will be organized in modules focused on important overall themes of the Chemistry and Physics of Nanomaterials. Within each module, specific topics will be presented and used to illustrate general concepts.

Module 1: Thermodynamics of Nanoscale Molecular Assemblies

- Introduction and review of chemical thermodynamics
- Molecular interactions and hydrogen bonding
- Introduction to concepts of statistical thermodynamics
- Hydrophobic effect and hydrophobic interactions at the nanoscale
- Electrostatic interactions and screening at the nanoscale
- Amphiphile assemblies (e.g., membranes and micelles)
- Polymer and biopolymer assemblies (e.g., protein-DNA interaction)

Module 2: Quantum Mechanics of Molecular and Nanoscale Systems

- Hamiltonian formulation
- Introduction to quantum theory and Schrödinger's Equation
- Matrix formulation of quantum mechanics
- Size dependent behavior (e.g., free-electron, particle in a box)
- Organic electronic materials (e.g., tight-binding (Hückel) theory and extensions)
- Size-dependent properties of nanomaterials (e.g., organic polymers or crystals)

Module 3: Spectroscopy and Dynamics

- Light-matter interaction, perturbation theory
- Absorption/emission spectroscopies
- Energy transfer
- Rate equation descriptions
- Exciton migration and light-harvesting

*There is some flexibility in choice of topics covered, and students are encouraged to discuss with the instructors early in the semester the possibility of covering other relevant topics that may be directly related to student research activities.

Overall Course Goals:

The course will provide students with:

(1) Knowledge of the power of using simple physical models to gain a conceptual understanding of the structure and dynamics of nanoscale materials.

(2) An understanding the energy, length, and time scales that pertain to nanoscale systems.

(3) Appreciation of how concepts from Chemistry, Physics, Biology and Materials Science intersect at the nanometer length scale, providing opportunities for insight that crosses disciplines.

Learning Objectives:

Upon completion of this course, all students will be able to:

(1) Analyze the behavior of nanoscale systems in terms of characteristic scales and units of length,

energy and time. (supports Goal 2)

(2) Develop models of nanostructure system properties based on physical and chemical principles, building upon knowledge in thermodynamics, quantum mechanics, and light-matter interaction. (supports Goal 1)

(3) Assess the validity and accuracy of assumptions that are invoked in models of the physical and chemical behavior of nanoscale materials. (supports Goal 1)

(4) Solve mathematical models of the physical and chemical behavior of nanoscale materials using appropriate mathematical and computational methods. (supports Goal 1)

(5) Produce descriptions of the structure and behavior of nanoscale materials by combining concepts from disciplines of Chemistry, Physics, Biology and Materials Science. (supports Goal 3)

In addition, graduate students will be able to:

6. Demonstrate an ability to read and critically evaluate an original research paper that focuses on nanoscience and nanotechnology. (supports Goals 1, 2 and 3)

Student Evaluation and Grading:

Undergraduate students (those enrolled in a 400-level course section)

Short assignments* (9 total expected, 50 points each, one dropped):	400 points
Summary assignments for each major topic* (3 expected, 100 points each):	300 points
Total	700 points

Graduate students (those enrolled in a 500-level course section)

Short assignments* (9 total expected, 50 points each, one dropped):	400 points
Summary assignments for each major topic* (3 expected, 100 points each):	300 points
Project/paper review assignment** (100 points):	100 points
Total	800 points

*In some cases, assignments may differ for graduate and undergraduate students. These situations will be described in the instructions for the particular assignment.

**Students enrolled in graduate classes will choose one of several research papers provided by the course instructors and develop an ≈4-page written paper that summarizes the published work and offers a critique of strengths, weaknesses and possible extensions of the work, as well as discusses connections of the paper to material covered in the class. More information on these assignments will be provided in class.

Consideration may be given for factors such as student improvement during the semester and overall participation (e.g., record of completed assignments). There may also be some opportunities for extra-credit. Final course grades may include a "curve" that takes into account the expectations of the instructors for performance on any given assignment. In general, letter grades may include +/- distinctions, but the awarding of an A+ will be reserved for those demonstrating consistently exceptional performance throughout the semester. Upon request, the instructor of record will provide students an estimate of their current letter grade at any time during the semester.

Assignment policies: Assignments may include both conceptual questions and problem solving. They will be due through the learn.unm.edu system on the announced due time and date, typically weekly for short assignments or biweekly for summary assignments. Students are responsible for ensuring that their assignment is submitted through the learn system on time (i.e., don't forget to click the "submit" button!) and as a readable document. Please follow instructions regarding the requested file formats for submissions. *It is strongly recommended that submissions not be left to the very last minute, and that students verify that their assignment has been submitted.*

Project/paper policy (graduate students only): The project/paper assignment for graduate students will involve a critical review of one of several possible journal articles provided by the instructors. The articles will be related to topics covered in class but may also include other topics that students will need to research on their own. The students will need to submit a paper that summarizes the published work and offers a critique of strengths, weaknesses and possible extensions of the work, as well as discusses connections of the paper to material covered in the class. Students may also discuss topics in the paper that were not clear to them and indicate steps taken to try to extend their knowledge in relevant areas. The course instructors will be available for consultation on the content of the journal articles, and the students may also discuss aspects of the chosen journal article with one another. However, the written paper submitted by students should be entirely their own work, and any contributions from any other sources must be appropriately acknowledged through standard use of citations.

II. NSME 512: Characterization Methods for Nanostructures

Instructor: Hien N. Pham
Email: hipham@unm.edu/ Phone: 277-9890 FEC Rm 1402 Department of Chemical Biological Engineering

COURSE DESCRIPTION:

Nanotechnology has revolutionized the world we live in, from our smartphones, computers, medical diagnostics, drug delivery and energy harvesting from the sun, to name a few examples. The remarkable properties of nanomaterials stem from their structure at the nanoscale. This course will help students learn the methods used to investigate nanostructures. Our emphasis is to explore the principles underlying commonly used techniques for nanostructure characterization. Students will learn how to interpret data from methods such as electron microscopy, scanning probe methods, x-ray and neutron scattering, optical microscopy and near field optical methods and surface analysis techniques such as XPS, Auger and SIMS. A particular focus of this course is to teach students to critically read the literature on nanomaterials and understand how these techniques are applied. The course will culminate with a project presentation where students will present a review of a newly developed technique that is relevant to their field of interest. Virtual or in-person lab tours and demonstrations will showcase the facilities available at UNM and elsewhere.

COURSE GOALS:

This course will help students:
• develop an understanding of how structure at the nanoscale determines the performance of nanomaterials
• develop an understanding of the physical principles that underlie commonly used materials characterization techniques
• develop the ability to perform a critical analysis of the literature in the field of nanotechnology
• demonstrate that they are able to learn about newly developed techniques for nanostructure characterization

STUDENT LEARNING OUTCOMES/COURSE OBJECTIVES:

After completing this course, students will be able to:
• explain why size affects material properties
• recognize the limitations and underlying principles of commonly used characterization techniques
• analyze data obtained from several commonly used nanomaterial characterization techniques

• perform critical analysis of published work to assess the validity of interpretations from nanoscale characterization techniques
• determine the most appropriate nanoscale characterization method for solving a materials research problem
• evaluate the principles and applications of a new technique in a final project presentation

PREREQUISITES AND CO-REQUISITES:

The course is open to senior undergraduate as well as graduate students, with different assignments and exams for graduate and undergraduate students. We welcome students from all STEM fields, for example

Engineering, Physics, Chemistry, Biology and Biochemistry. There are no prerequisites, but it is expected that you have completed the required physics, math and chemistry courses in your major (at the junior level). This is a core course for students pursuing the NSME graduate degree; for all others it will count as an elective.

TEXTBOOK AND SUPPLEMENTAL MATERIALS

REQUIRED TEXTBOOKS:

No textbook is required since much of what will be discussed is available in reading materials, videos and websites, as well as some excellent review articles that will be provided via UNM Canvas.

READING MATERIALS AND LITERATURE ARTICLES:

Reading materials and literature articles on topics covered in the course will be provided so that you will have of time to familiarize yourself with the materials before assignments are due.

REQUIRED SUPPLEMENTARY MATERIALS:

American Mineralogist Crystal Structure Database (AMCSD), CrystalViewer Software, Kaltura Media, ImageJ Software

PROCEDURES FOR COMPLETING COURSEWORK:

- *For each module, which is released every Thursday, students will submit their assignments on Saturday and Wednesday by midnight.*
  - *If you anticipate a difficulty submitting assignments by the due date, you have one week past the due date to submit them, but you must let us know so we won't post solutions for one extra week. Once solutions are posted, no late assignments will be accepted.*
  - *All assignments must be submitted on UNM Canvas. If you have difficulty submitting them, use the "Submit a Support Ticket" link in the Help Menu immediately and notify me as well.*
- *Students will be given two take-home exams: the first one given during mid-semester and the second given during finals week.*

COURSE SCHEDULE

Module	Release Date	Topics covered	Points Synchronous Recitation **All students**	Points Assignments Parts I and II **All students**	Additional Points Assignment Part III **Graduate students only**
Welcome	8/22	**Course introduction**	-	25	-
1	8/25	**Why Nano?**	5	25	10
2	9/1	**How we study nanostructures**	5	25	10
3	9/8	**X-ray Diffraction (Theory)**	5	25	10

4	9/15	**X-ray Diffraction (Applications & Data Analysis)**	5	25	10
5	9/22	**Introduction to Reciprocal Space**	5	25	10
6	9/29	**Electron Diffraction**	5	25	10
7	10/6	**Exam I**	-	100	40
8	10/13	**Transmission Electron Microscopy (CTEM, HRTEM, STEM)**	5	25	10
9	10/20	**Resolution, Phase Contrast, Aberration Correction**	5	25	10
10	10/27	**SEM, Analytical Electron Microscopy (EDS, EELS)**	5	25	10
11	11/3	**Scanning Probe Methods (STM, AFM, etc.)**	5	25	10
12	11/10	**Surface Analysis Techniques (XPS, AES, LEIS)**	5	25	10
13	11/17	**Optical Microscopy**	5	25	10
14	12/1	**Case studies**	5	25	10
15	12/1	**Project Presentations**	5	50	-
16	12/9	**Exam II**	-	100	40

EXPECTATIONS FOR PARTICIPATION:

- *Time required: 8-10 hr per week*
- *Students are expected to communicate with one another on group assignments*
- *Students are expected to keep abreast of course announcements*
- *Students are expected to keep me informed of course-related problems, or problems that may prevent the student from full participation*
- *Students are expected to address technical problems immediately*
- *Students are expected to observe course netiquette at all times*

MANDATORY WEEKLY 1-HR SYNCHRONOUS RECITATION:

Beginning the week of August 29th, students are required to attend the 1-hr synchronous recitation on ZOOM every week, except during the week of exams. Synchronous recitation allows students a chance to interact face-to-face with the instructors and with other students on a weekly basis. These recitations allow instructors to explain concepts and help students with their assignments. In some cases, we may use the synchronous recitations for tours of UNM labs. Students will turn in their recitation assignments by Wednesday at midnight to get credit towards their final grade (see Course Schedule).

GRADING PROCEDURES:

- *Grades are done using a rubric for assignments, exams and discussion forums*
- *Grading response time is within a week after solutions have been posted, and late assignments are no longer accepted once a solution is posted*
- *Grades are weighted as follow: recitation is 5%, assignments are 25%, exam is 25% each, and project presentation is 20%*

GRADING SCALE:

Final grades will be based on the sum of all possible course points as noted above. Percentage of available points:

GRADES:

97 – 100	A+
93 – 96	A
90 – 92	A-
87 – 89	B+
83 – 86	B
80 – 82	B-
77 – 79	C+
73 – 76	C
70 – 72	C-
67 – 69	D+
63 – 66	D
60 – 62	D-
< 60	F

III. NSME 518: Nanomaterials Synthesis

Instructor: Nick Carroll (CBE) and Lok-kun Tsui (CMEM)

	Prof. Carroll	**Prof. Tsui**
Office Hours	by appointment	by appointment
Email and Phone	ncarroll@unm.edu / 505-859-0554	lktsui@unm.edu / 505-925-5987

PREREQUISITE

General knowledge of chemistry and thermodynamics is highly recommended for this course. You may use any undergraduate introductory chemistry and thermodynamics textbook which may be found in the UNM library as a reference.

SCHEDULE OF TOPICS

Nick Carroll (Molecular and Colloidal Assemblies) Aug 24 – October 5

Week 1.1 – Units/Natural Scales, Review of Classical Thermodynamics

Week 1.2 – Probability and Statistics, The Statistical Basis of Entropy

Week 1.3 – Boltzmann Distribution, Intermolecular Assemblies

Week 1.4 – Polymer Chemistry: Nomenclature and Classifications, Mean Field Theory

Week 1.5 – Polymer Phase Separation, Phase Diagrams, Polymer and Protein Assemblies

Week 1.6 – Colloidal Assemblies: Hydrophobic effect, Electrostatics: Poisson-Boltzmann

Week 1.7 – Project Presentations

Lok-kun Tsui (Additive Manufacturing Technologies) Oct 12 – Dec 7

Week 2.1 - Additive Manufacturing Overview and Motivations

Week 2.2 - AM of Polymers

Week 2.3 - AM of Ceramics

Week 2.4 - AM of Metals

Week 2.5 – AM for Printed Electronics

Week 2.6 – Applications of AM in electrochemical systems / Demonstration Day

Week 2.7 – Project Presentations

COURSE MATERIALS

The instructors will provide topic notes that will be posted in the course information folder. Students will also be directed to review papers on the topics covered by this course as the course proceeds.

○ ASSIGNMENTS

There will be eight homework assignments worth 5 pts each, four from each half of the semester, account for total 40% of the final grade. The other 60% comes from two in-class presentations towards the end of each half of the semester.

Homework	40%
1st presentation	30%
2nd presentation	30%
Total	**100%**

Late homework policy: Late homework's will not be accepted. If there are circumstances that prevent a timely homework submission (job interview, grad school visits, etc.), please email the professor in advance for an extension.

IV. NSME 519: Advanced Micro and Nano Systems Engineering

Instructor: Nathan Jackson (ME)

Course Description: Introduction to principles and theory of advanced microfabrication techniques, and applications of microelectromechanical systems (MEMS). Covers the theory and fundamentals of microfabrication including photolithography, thermal oxidation, PVD and CVD, etching, implantation, diffusion, and process integration, and packaging. Hands on experience with manufacturing of MEMS devices and process engineering using the MTTC cleanroom facilities will be performed in the lab. The information in this course is targeted towards MEMS but the principles apply to semiconductor manufacturing as well.

Goals: To introduce you to the world of MEMS and NEMS, and to become familiar with both the theory, and practical issues related to advanced microfabrication techniques. In this course you will get hands-on experience in microfabrication and gain knowledge and experience in MEMS and NEMS devices through problem-based learning.

Course Objectives:

- Identify real-world applications involving MEMS devices
- Develop and critique a microfabrication process flow for a basic MEMS device
- Calculate and Model complex oxidation and doping kinetics
- Compare and Contrast thin film deposition and etching methods
- Evaluate and Develop new MEMS Applications and Fabrication

Required Textbook

Introduction to Microfabrication 2nd edition by Sami Franssila

Optional Texts

Introductory MEMS Fabrications and Applications by Thomas Adams and Richard Layton
Foundations of MEMS by Chang Liu
Fundamentals of Microfabrication by Marc Madou
Microsystem Design by Stephen Senturia
MEMS Packaging by Tai-Ran Hsu

Course Topics

1. Introduction to MEMS- Overview and History of MEMS, Cleanroom facilities, and scaling laws
2. Theory of Advanced Microfabrication
    a. Semiconductors
    b. Photolithography
    c. Thermal Oxidation
    d. Diffusion and Doping
    e. Physical vapor deposition methods
    f. Chemical vapor deposition methods
    g. Epitaxial Growth
    h. Etching- Dry/wet, anisotropy
    i. Process Integration
        i. Surface micromachining- process integration, stiction, residual stress, etc…

ii. Bulk Micromachining
iii. Soft Lithography
iv. LIGA

j. Packaging

3. Materials used in Microfabrication
    a. Silicon
    b. Smart Materials
    c. Polymer MEMS
4. Transduction mechanisms
    a. Piezoelectric
    b. Magnetic
    c. Thermal
    d. Piezoresistive
    e. Electrostatic

Laboratory

3-hour durations held at MTTC time and day (Tuesday, Thursday (could replace with Wed if desired), Friday 7:30m-10:30am)

Team Project

The project will be described in more detail during the semester, but it will consist of: a) project concept, b) project proposal, c) presentation and d) participation in a mock evaluation panel.

Grading:

1. Midterm Exam 20%
2. Final Exam 25%
3. Lab 25%
4. Project 20%
5. Homework 10%

Tentative course outline

Week	Material
Week 1	Introduction to MEMS and History of MEMS
Week 2	Laws of Scaling and Overview of MEMS manufacturing
Week 3	Introduction to Silicon
Week 4	Oxidation and Doping & Lab 1
Week 5	Photolithography
Week 6	Photolithography & Lab 2

Week 7	Thin Film Deposition
Week 8	Etching & Lab 3
Week 9	Spring Break
Week 10	Midterm and Lab 4
Week 11	Transduction Mechanisms and Lab 5
Week 12	Surface Micromachining
Week 13	Bulk Micromachining and lab 6
Week 14	MEMS Packaging and lab 7
Week 15	BioMEMS and lab 8
Week 16	Project Presentations and Review

Lab Schedule:

Lab 1- Art Wafer- week of Feb 8th-11th

Lab 2- Doping Lab- Week Feb 22nd-25th

Lab 3- Lift-off Process- week of Mar. 8thth-11th

Lab 4- Soft lithography- week of March 22nd-25th

Lab 5- Etching (microneedles)- week of March 29th-April 1st

Lab 6, 7, and 8 MEMS Actuator (one single lab report)

- Lab 6- Week of April 12th-15th
- Lab 7- Week of April 19th-22nd
- Lab 8- Week April 26th-29th

V. NSME 550: Responsible Conduct of Research and Nanotechnology

Instructor: William Gannon Ph.D (Biology)

In this course, students will examine issues arising from this emerging technology, including those of privacy, health and safety, the environment, public perception and human enhancement. They will become aware of their responsibilities and role for conducting research with integrity.

Course Description

Responsible Conduct of Research (RCR) is the practice of scientific investigation with integrity. It involves awareness and application of established professional norms and ethical principles in performance of all activities related to scientific research. It also includes most of the professional research activities that are coming under increasing regulatory scrutiny.

As of 4 January 2010 for NSF and 26 January 2010 for NIH, any researcher supported by NIH or NSF should be concerned about RCR requirements. Post-docs, graduate students, and undergraduate students supported by funding must receive RCR instruction within 1 year of the award. Including NSF and NIH, funding agencies have different requirements, but UNM has set certification good for 4 years before a refresher course is taken. More detailed information on the UNM standards (Scientific Integrity Plan; SIP) can be found at http://research.unm.edu/researchethics/ .

Course Requirements and Policies

1) Email and Internet Access

I will post class announcements, course materials, and presentations on DropBox (http://www.dropbox.com/). Therefore, you must have reliable and regular access to the internet and do not need a UNM username and password. I will provide instructions on accessing drop box the first class period.

2a) Required Texts

- *On Being a Scientist* (PDF and hardcopy provided)
- *Frankenstein* by Mary Shelley (the original 1818 text edited by DL MacDonald and K Scherf (ISBN 1-55111-308-2) or any other original version, in any media

Suggested Text:

- Macrina, F. L. 2005. *Scientific Integrity* (Third Edition) text and cases on the responsible conduct of research: ISBN 1-55581-318-6

2b) Handouts provided – many current examples of RCR content from literature will be provided either in hard copy or at NSMS 550 Drop Box.

7) **NSMS 550: Tentative Schedule for Weeks 1-6**

The schedule of topics we will cover may vary; however we will meet every Tuesday as scheduled. **Regularly check NSMS DropBox** for new materials. Assignments can be emailed to wgannon@unm.edu and/or placed in student folder on DropBox.

	TOPIC	READINGS

WEEK 1 18 Sept	Introduction to RCR and Research misconduct- Plagiarism, Fabrication, Falsification	*On Being a Scientist,* and *Research Ethics* paper See DropBox
WEEK 2 25 Sept	Human and other animals in research; Whistleblower ethics; Begin Mentoring	*Assignment I* *Scientists Behaving Badly* handout; Mentoring from *Nature*
WEEK 3 2 Oct	Mentoring workshop	ORI *The Lab: Avoiding Research Misconduct* interactive video; "Bring your mentor to class" day
WEEK 4 9 Oct	Conflict of interest and commitment and Authorship, publication, sharing peer review Also, Data acquisition, management, ownership	Handouts; be sure to read Frankenstein.
WEEK 5 16 Oct	Collaborative research, (incl with industry) The scientist as a resp member of society Issues in Nanotechnology	Prepare one page summary of an issue (these will be prompted) due. Presentations and Guest Speaker
WEEK 6 23 Oct	Issues in Nanotechnology Wrap up, summary, case study discussion	Presentations and Guest Speaker Case studies; final paper due; assessment