PhD Student Handbook
Biomedical Engineering (BME)

March 2024

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BME GRADUATE PROGRAM GENERAL PROCESSES AND CONTACTS

For general questions, students should first consult their research advisor and the Vanderbilt Graduate School website. On the graduate school website, the Vanderbilt University Student Handbook and Vanderbilt University Graduate School Catalog can be found, in addition to other resources such as academic forms, graduation checklist and deadlines, applications for research travel grants and other professional development opportunities, and information related to health and wellness. Students are also able to pursue additional support available through the University Counseling Center (UCC), the office for International Student & Scholar Support (ISSS), the Center for Teaching (CFT), the Career Center, and others.

This handbook is a complement to the graduate school resources and should be consulted, along with the research advisor, by BME graduate students for more program-specific information on regulations and requirements. There is some overlap in the handbook content with information maintained by the graduate school. If there are future updates that cause a discrepancy between graduate school guidelines and this document, the graduate school will be generally considered the ultimate resource for procedures, regulations, and graduation requirements. However, this is not always the case. For example, the minimum number of didactic credit hours defined by the graduate school for a Ph.D. is 24; the BME requirement of 27 credit hours supercedes the grad school minimum. If a discrepancy or gap in important information is noticed, please notify the Director of Graduate Studies to seek clarification and/or to request updates to the BME Program Handbook.

After consulting the research advisor, the graduate school website, and the BME graduate handbook, students needing further support should contact the BME Graduate Program Coordinator. They will provide additional information to the student's as they are able and will also, as needed, bring in additional support from the BME Director of Graduate Studies, BME Director of Graduate Recruiting, BME Department Chair, and/or centralized support staff at the Graduate School.

Note that work hours and vacation policies are lab-specific and set by the PI. Students should communicate with their advisor and be sure to have clarity on day-to-day research expectations, both during the academic year and summer.

Forms

Information on forms needed at various milestones is provided at the end of this document. Students should contact the Graduate Program Administrative Coordinator if additional support is needed with finding required forms, for seeking the signature of the Director of Graduate Studies, or for submission of completed forms.

Variances

Students wishing to request variances in didactic requirements or required timelines should first get approval of their research advisor and then contact the Director of Graduate studies. One example request would be related to counting engineering courses taught outside of BME toward the BME elective requirement. Note that classes must be engineering courses related to a biological or biomedical topic to receive consideration. Another request that can be considered under special circumstances is delay of the Qualifier Exam until after the third year. This should be avoided, if possible, but can be considered if a student changes projects or faces other extreme challenges. Note that the Graduate School has an absolute requirement that doctoral candidacy must be achieved no later than the fourth year.

Lab / PI Grievances

Students should first consult their advisor to address grievances related to their project or other lab personnel. If issues cannot be resolved "locally", the student should contact the Director of Graduate Studies, who will then intervene and/or direct the student to additional resources. Many students find it helpful to meet with a Vanderbilt Graduate Life Coach or Academic Success Coordinator (https://gradschool.vanderbilt.edu/student-resources/professional-development/gpas/) to discuss and receive guidance on managing personal conflicts within the lab or with the student's advisor. Note that a Graduate Life Coach can also help students who are facing personal or other challenges during graduate school beyond laboratory conflicts.

Contact Information

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Craig Duvall, Ph.D.- Director of Graduate Studies
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RESEARCH EXPECTATIONS / TRAINING FOR THE PROFESSION

Responsible Conduct of Research (RCR)- All students are required to receive training on RCR.

Fellowships and Publishing- It is expected that all eligible students apply for prestigious graduate research fellowships from sources such as NSF, NIH, DOD, and relevant foundations. It is also expected that students will publish their work in leading biomedical and engineering research journals and present their work externally at national conferences such as the Biomedical Engineering Society Annual Meeting. Students should consult directly with their advisor for lab-specific guidelines on hours spent on research, vacation time, publishing requirements, intellectual property, moonlighting, etc. Outside moonlighting or consulting should be approved by both the PI and the DGS.

Supplemental Experiences**-** Students are encouraged to take advantage of the opportunities provided to them throughout their studies. Examples include: 1) pursuing a teaching certificate from our Center for Teaching (CFT) for students who are considering an academic/teaching career; 2) pursuing entrepreneurship opportunities through internships, the NSF i-Corps program, or our 'Innovation Realization' course that is offered jointly with the Vanderbilt Law School and the Owen School of Management.

Teaching- There is no strict requirement for serving as a teaching assistant as part of the BME Ph.D. program. However, the majority of Ph.D. students will complete 1-2 TAships, often but not always in the first year of the program. TA obligations will require up to 15-20 hours per week and include some or all of the following: answering students' questions, holding office hours, grading, generation of content for teaching or assessments, assisting in undergraduate lab courses, and lecturing.

REQUIREMENTS TO PROGRESS TOWARDS THE DEGREE (PHD AND MS)

Master of Science Coursework Requirements

Candidates for the master of science (M.S.) degree must complete 30 hours of graduate-level credit. At least 24 credit hours must be didactic, and these cannot be pass/fail. The didactic credit hours should be distributed as follows:

- Biomedical Engineering: minimum of 12 credit hours
- Life Sciences: 3 credit hour, 6000-level or above course taken from the list below or approved by the research adviser and Director of Graduate Studies:
    - CANB 8340 - Introduction to Cancer Biology
    - CANB 8342- Advanced concepts in cancer biology
    - CBIO-8324 - Epithelial Pathobiology
    - CBIO-8341 - Stem/Progenitor Cell and Regenerative Biology
    - HGEN 8340 - Human Genetics I
    - IGP 8002 - Bioregulation II
    - M&IM 8329 - Principles of Immunology and the Immune System in Disease
    - M&IM 8334 - Special Topics in Molecular Pathogenesis
    - MP&B 8330 - Human Physiology and Molecular Medicine
    - NURO 8327 - Graduate Neuroanatomy
    - NURO 8340 - Fundamentals of Neuroscience II
    - NURO 8345 - Fundamentals of Neuroscience I
    - NURO 8347 - The Visual System

- PATH-GS 8339 - Foundations of Immunology
- PATH-GS 8345 - Human Biology and Disease
- PATH-GS 8351 - Cellular and Molecular Basis of Disease

- Advanced Engineering/Science: minimum of 9 credit hours

*At least 6 of the BME hours and 3 of the advanced science or engineering hours must be 6000+ level courses. A total of 6 credits can be counted from one (1) hour of BME seminar and thesis research credit hours toward the required 30 credit hours. M.S. candidates must also submit a research thesis to their faculty advisor and another faculty reader, in addition to giving a final oral presentation to the department.

Doctor of Philosophy Coursework Requirements

Candidates for the Ph.D. degree must complete a minimum of 27 credit hours of graduate-level didactic courses. Didactic credits cannot be taken on a Pass/Fail grading basis. The credit hours should be distributed as follows:

- Biomedical Engineering: minimum of 15 credit hours
  - BME 6110 Intro to Research and Professional Development is required; counts toward 15 required
  - ChBE classes on Immunoengineering (5820) and Biomolecular Engineering and Design (5805), along with the EECE Advanced Image Processing (6357), can be counted as BME courses. One other engineering course taught outside of BME but that has a biological or biomedical focus can also be counted with the approval of the Director of Graduate Studies. Additional engineering courses can also be considered to count toward the BME course requirement but requires departmental approval.
- Life Sciences: 3 credit hour, 6000-level or above course taken from the list below or approved by the research adviser and Director of Graduate Studies:
  - CANB 8340 - Introduction to Cancer Biology
  - CANB 8342- Advanced concepts in cancer biology
  - CBIO-8324 - Epithelial Pathobiology
  - CBIO-8341 - Stem/Progenitor Cell and Regenerative Biology
  - HGEN 8340 - Human Genetics I
  - IGP 8002 - Bioregulation II
  - M&IM 8329 - Principles of Immunology and the Immune System in Disease
    *only 2 credit hours so must be supplemented with another course
  - M&IM 8334 - Special Topics in Molecular Pathogenesis
  - MP&B 8330 - Human Physiology and Molecular Medicine
  - NURO 8327 - Graduate Neuroanatomy
  - NURO 8340 - Fundamentals of Neuroscience II
  - NURO 8345 - Fundamentals of Neuroscience I
  - NURO 8347 - The Visual System
  - PATH-GS 8339 - Foundations of Immunology
  - PATH-GS 8345 - Human Biology and Disease
  - PATH-GS 8351 - Cellular and Molecular Basis of Disease
- Advanced Engineering/Science: minimum of 9 credit hours

*Of the 27 required didactic credits, at least one course is required to be <u>strongly quantitative</u>. It must either come from the list below or be approved by the student's mentoring committee. BME 7410 is especially recommended to satisfy this requirement.

- BME 7310 - Advanced Computational Modeling and Analysis in BME
- BME 7410 - Quantitative Methods in Biomedical Engineering
- BME 7450 - Advanced Quantitative and Functional Imaging
- CS 5267 - Deep Learning; EECE-5356 - Digital Signal Processing
- CS 8395- Special Topics: Open-source Programming for Medical Image Processing
- EECE 6357 - Advanced Imaging Processing
- EECE 8396 - Special Topics: Analysis of Functional Magnetic Imaging
- MATH 5670 - Mathematical Data Science
- MATH 6630 - Nonlinear Optimization
- MSCI-5009 - Biostatistics I
- PHYS-8005 - Mathematical Methods for Physicists

*At least 6 of the BME hours and 3 of the advanced science or engineering hours must be 6000+ level courses.

*The remainder of the 72 hours required for a Ph.D. will typically consist of dissertation research but may also include seminar and other didactic courses.

TRANSFER CREDIT

Graduate level courses taken from another institution can be considered for transfer and to count toward the Vanderbilt graduate degree requirements if (1) a grade of B or higher was earned and (2) the course credit was not applied toward the requirements for earning a prior (*e.g.*, undergraduate) degree. Up to 6 credit hours can be transferred toward the master's degree, and up to 48 credit hours can be transferred toward the PhD. Please acquire an official transcript that displays the course(s) to be transferred and contact the Graduate Program Coordinator to initiate the process. Regardless of number of credit hours transferred, all students are required to take at least 2 graduate-level BME didactic courses at Vanderbilt for a total of at least 6 credit hours.

ADVISOR SELECTION AND MENTORING COMMITTEES

Advisor selection- Most incoming BME students will match with their research advisor during the interview and recruitment process that occurs prior to matriculation at Vanderbilt. However, matching with a research advisor in advance is not required, and students are allowed to rotate or otherwise further consider research labs during their first semester. There is not a formal rotation length or process, and students are required to organize that individually or with the help of the Director of Graduate Studies, as needed. All students should match with their advisor by the end of their first semester in the program. The advisor matching process is negotiated between the student and the faculty member, and a form is submitted by the student to formally declare their advisor.

Mentoring committee and meetings- All students must meet with a mentoring committee each semester (fall and spring) after entering the program until they form their dissertation committee. This typically entails 4 meetings over the first 2 years of the program. The mentoring committee is assigned by the Director of Graduate Studies and comprises 3 faculty, including the student's primary research advisor. Mentoring committee meetings are 30 minutes in length, during which time the faculty committee assesses the student's research and coursework progress. The student is given constructive feedback if there is a concern. It is expected that the student will show improvement in areas of concern by the next mentoring committee meeting. The mentoring committee can recommend that the student exit the program with a terminal M.S. degree if the student is not ultimately able to correct their course after having received critical feedback in previous mentoring committee meetings.

DISSERTATION COMMITTEE FORMATION

The dissertation committee should be formed, in consultation with the student's advisor, early in the 3rd year of the program. The dissertation committee comprises 5 faculty members, including the research advisor, who is the chair of the committee. At least 3 committee members must be BME faculty members, and at least 1 must be a primary BME faculty member. At least 1 committee member must be from the school of medicine (clinical or basic sciences); with approval, this committee member can also be from a medical center outside of Vanderbilt. The dissertation committee is responsible for administering the PhD qualifier exam and the oral examination at the student's PhD defense. The qualifier exam should be completed before the end of the 3rd year in the program. Students are also required to organize one pre-qualifier meeting with their committee to introduce themselves and their work and to get preliminary feedback prior to the formal qualifier exam. The committee should receive the written proposal and written dissertation documents at least 2 weeks in advance of the in-person examinations.

Timing- The committee can be established first with 3-4 rather than the full 5 members. The committee should be established and a pre-qual meeting held by the first semester of the third year. If a partial committee is initially formed, the full committee should be formed in advance of the Qualifier Exam.

QUALIFYING EXAM

Pre-Qual Meeting- A pre-qual meeting should occur in the fall semester of the 3rd year and should be scheduled following approval by the mentoring committee and research advisor. This meeting should include at least 3 committee members (counting the student's PI), and at least 1 must be a primary BME faculty. This can be either a group meeting or can be a series of individual meetings between the student and the committee members. In this meeting, the student will give a brief introduction to their research project and potential proposed aims. The purpose of this meeting is to allow the student and committee members to become familiarized with each other in advance of the Qualifier Exam. It also serves as an opportunity for committee members to make suggestions regarding the aims or scope of work in advance of the student fully writing up the research proposal document.

Degree Audit- Before scheduling your Qualifying Exam, please review your degree audit in YES. You will not be allowed to schedule your exam if you have not completed at least 24 didactic courses toward the degree requirement, and many students will have completed all coursework prior to taking the Qualifying Exam. If you have courses that are not allocating into coursework categories correctly in the degree audit, please send an email to Professor Duvall and Peter Nordberg to request it be assessed for correction. Please clearly indicate in this message the course number and what coursework requirement it should be applicable for. After this has been approved by Professor Duvall, a request will be sent to the Graduate school to make the changes in YES.

Qualifying examinations will be given in accordance with the regulations of the Graduate School and administered by the Ph.D. committee. Predoctoral students are expected to advance to candidacy by passing the qualifier exam before the end of their 3rd year. Students must have completed 24 didactic hours prior to taking the qualifying exam. The qualifying exam will consist of a written proposal and an oral presentation and defense of the proposal.

The Qualifier Exam may probe concepts both directly and indirectly related to the dissertation proposal. The examination can be taken a maximum of two times. Outcomes for each exam can include: pass, fail, or pass with stipulations. For the latter, a student may be required to take a course on a specific topic or be required to provide an updated version of the written proposal to the committee in follow-up communication. In this case, another full examination meeting may not be required if the student can sufficiently satisfy the committee's concerns by providing revised and/or appended information in follow up electronic communication.

The written proposal should be developed in consultation with the research advisor and should detail the dissertation project research plan. This proposal should ideally include preliminary data generated by the student to support and justify the project. The written document must be sent by the student to the PhD committee at least 2 weeks prior to the examination. The format of the written proposal is flexible, but it is recommended to follow the format of an NIH R01 proposal, which is allowed to be up to 13 single spaced pages in length (1 page for specific aims; 12 for the remaining sections; references cited section does not count against the page limit). Students are encouraged to write in 1.5 line spacing and adjust the page length accordingly; page recommendations provided here and below are based on single spacing. Margins should be at least 0.5 inches, and font should be a minimum of 11 point. The proposal should include the following sections.

(1) The Specific Aims should be a 1-page section of the proposal. This section summarizes the motivation for the research, project innovation, and significance in the first 1-2 paragraphs. This is followed by a clear statement of the overall goal of the project; this can be either a design-related goal or statement of a central hypothesis to be tested in the work. After this statement, the specific aims (typically 3) of the project should be outlined. At the end of the specific aims page, the impact of the work can be re-stated, and mention should be made, if applicable, of how collaborating labs or a broader research team will contribute to the success of the project.

(2) Significance of the work should be clearly stated in terms of how it addresses an unmet medical need or fills a fundamental gap in the understanding of biological processes. This section will typically be ~1-2 pages and include a brief review of the mostly closely related literature. The function of this section is to

provide the "lay of the land" in the dissertation research area and to clearly identify the gap in knowledge/technical capability or unanswered question(s) that will be addressed by the proposed work.

(3) An Innovation section is also included to emphasize the novelty of the proposed work. Innovation can be conceptual or technical in nature. Use of cutting edge methods or new application of existing methods should also be described here. If the project is design oriented, previous or competing technologies should be clearly described along with clarification of how the proposed work will improve upon them. This section is typically ~1-2 pages.

(4) The Approach section is the heart of the proposal (~8-10 pages). The approach section details the planned experiments that comprise each of the proposed research aims. There will be a subsection of the Approach dedicated to each of the proposed aims. There will also be subsections in the proposal included for each aim. These will include at least 3 sections under each aim describing: (i) premise for the proposed research aim- this can include the student's own preliminary data, data from the student's research lab, and/or support from the literature to justify the aim; (ii) description of the experimental plan for the aim, including methodological details; (iii) rigor and reproducibility- provide details of statistical plan including a power analysis to support sample size for all experiments. See section below further explaining the use of and need for preliminary data.

(5) There is no strict requirement in terms of how much preliminary data is included, but it is expected that preliminary data supporting the feasibility of the project will be included. The captions of preliminary data figures should include sample size, statistical test used, and any other information critical to understanding the data set shown. Each caption should, at the end, include a statement of whether the data set was generated by the PI's lab, fully by the candidate, or in part by the candidate. Preliminary data can be provided as a separate section of the document (prior to the approach section). Alternatively, preliminary data can be mixed in with other sections of the proposal; for example, relevant preliminary data could be shown in the innovation section or at the front of each research aim subsection within the Approach section.

(6) Include a statement on IACUC or IRB protocol approvals needed for the work and the current status of those protocols.

(7) A proposed timeline for project completion and defense of the dissertation research should be included.

(8) References cited will be provided at the end of the document and do not factor into the page number. Use a reference software such as Endnote. Please consult with your PI first to learn about lab preferences for reference management software; some reference softwares are not cross-compatible, creating problems for working with other authors on manuscripts, grant proposals, etc. Choose a reference style that includes the full author list, manuscript title, and journal information.

The oral portion of the qualifier exam should be scheduled for a 3 hour block with the committee. The student should bring all required paperwork to the meeting (qualifier exam outcome form and SACS form). In the oral qualifying examination, the student should be prepared to demonstrate competency with fundamentals in the inderdisciplinary areas related to the research and should demonstrate in-depth knowledge of subject matter directly related to the dissertation project

At the start of the exam, the student will be asked to leave the room for 5 minutes for a brief preliminary discussion among the committee. Upon the invitation to re-join the committee, the student's PI will introduce them and the presentation will commence. The presentation should include a background section that will serve to introduce the committee to the area of research and define the overall goal and significance of the project. The student will then outline the aims of the project, followed by going into a detailed description of the premise, experimental plan, and statistical considerations for each aim. As relevant, the student should show and provide their interpretation of the preliminary studies that have been done for each aim. In some instances, the first aim of the project may be mostly completed or even published. The student should still review their data from those studies with the committee. The student should expect to be interrupted at times during the presentation

whenever examination opportunities arise in the eyes of the committee. Example questions that may arise include: Asking the student to describe the advantages and disadvantages of a model system being used in experimentation; Asking a student to provide a more in-depth explanation of a method that will be applied in the work; Asking a student to describe a signaling pathway or fundamental biological process that underlies their planned experimentation; Asking a student to relate new data to previously-published work; Asking a student to describe the planned statistical or analysis methods. This is not intended to be a comprehensive list but rather to provide examples of the types of questions students should expect.

COMMITTEE UPDATE MEETINGS

Students should meet with their PhD committee no less than 1 time per year between the Qualifying Exam and the Defense. Typically, the final committee meeting will be within 3-6 months of the defense. In this meeting, the student should have accomplished a large percentage of the work that will comprise the dissertation and should seek to get approval from the committee to schedule the defense date.

DISSERTATION AND DEFENSE GUIDELINES

PhD candidates must write a dissertation showing the results of original research in biomedical engineering. Students must defend within 4 years of gaining PhD candidacy. Please reference the graduate school calendar to determine the deadline for final dissertation submission for graduation in a given semester. Because the committee may request dissertation edits prior to it being considered final, students are advised to schedule the defense to occur well in advance of the Graduate School's dissertation submission deadline. In most years, May graduation requires defense in mid-March at the latest.

The written dissertation is presented to the faculty dissertation committee at least two weeks in advance of the public presentation. The dissertation formatting and submission guidelines can be found here. A BME dissertation at a minimum comprises the following core chapters: (**1**) an in-depth introduction, similar in nature to a review article, that summarizes the published work related to the topic of the student's research. (**2**) 2-3 or more "research" chapters; each chapter typically summarizes the results from one of the overall project aims. Often, each research chapter comprises the content that has or will be used in publication of a journal article. (**3**) A summary chapter should be included that summarizes the overall conclusions of the work and clearly describes the contributions to the broader research field. This chapter should also have a section on the broader impacts of the work. A section should also be included that indicates gaps or limitations in the work and identifies future steps for the project. (**4**) Finally, an appendix should be included that includes research protocols and or supplementary/supporting information not included in the chapters. Including protocols that go beyond what is provided in the methods section of the chapters (or a typical journal publication) can be helpful as a reference for future researchers who may work on similar projects.

The presentation of the work is open to the public and is followed by a closed-doors oral examination of the candidate by the faculty dissertation committee. Three hours should be scheduled for the defense presentation and examination. The defense presentation should be approximately 40 minutes in length. With a 5-minute introduction and 15 minutes for general audience Q&A, this will keep the public portion of the defense to ~1 hour. Afterward, all attendees will be cleared from the room, and the student will be examined by the Ph.D. Committee for 1-2 hours. The defense examination may include concepts both directly and indirectly related to the dissertation research. Outcomes for the defense can include: pass, fail, or pass with stipulations. For the latter option, students are sometimes asked to make and send out edits to the dissertation document prior to the committee fully signing off on the dissertation. The committee can also, at their discretion, require an additional in-person meeting before a final determination is made on the defense outcome.

FORMS

The forms required by the Vanderbilt Graduate School are maintained at this link. Commonly used Graduate School forms, in addition to forms required by the BME department, are listed below. Please refer to the graduate school website above for forms that apply to more specialized situations, as other less commonly-used forms are found there but not listed on this document. The forms listed in *italics* are department-specific forms, and

those will not be found on the graduate school website. For all forms, including those that go to the Graduate School, please send them first to the BME Graduate Coordinator for review, help getting the signature of the BME Director of Graduate Studies, and formal submission.

- ❑ **Request to appoint advisor**; submitted in first year, typically upon matriculation, no later than end of spring semester.

- ❑ ***Mentoring committee meeting*** *form; submitted with each mentoring meeting in first two years, typically four times total.*
  **Mentoring committee presentation should be prepared using the linked template.*

- ❑ **Ph.D. committee appointment** form; submitted early fall of third year.

- ❑ **Pre-qual meeting** form; submitted by end of fall semester third year.

- ❑ Request to **schedule qualifier exam**; before end of spring semester third year; submit at least two weeks before qualifier date.

- ❑ **Qualifier exam results**; before end of spring semester third year; sent to program coordinator (with all signatures) asap after completion of the qualifier exam.

- ❑ *Southern Association of Colleges and Schools* ***(SACS) qualifier exam*** *form. Program accreditation related form completed by committee at the end of the Qualifier Exam; signed form is returned by the committee to the student who submits to graduate coordinator.*

- ❑ **Intent to Graduate**; submit early in graduating semester.

- ❑ **Request to schedule defense**; submitted at least two weeks before the defense date. See graduate school calendar to determine the deadline for final dissertation submission to be able to graduate in a given semester. Note that a defense typically needs to be held in early to mid-March to meet the timeline to graduate in May.

- ❑ **Defense results**; sent to program coordinator (with all signatures) asap after defense.

- ❑ **Other defense forms**: Take copy of **title page** and **abstract** to the defense to get the required committee signatures.

- ❑ **Southern Association of Colleges and Schools Form**: This program accreditation-related form filled out by the committee at the end of the defense; signed form is returned to the student who submits it to the graduate coordinator.

TRAVEL AND REIMBURSEMENT PROCESSES

If you are going to travel on university business, please read the Vanderbilt Travel Policy. This policy applies to you as a graduate student and explains the details for planning your trip, where to purchase an airplane ticket, etc. To summarize the travel process in a few steps please see below:

1) Acquire written preapproval for your trip from your PI, including the funding source(s).
2) **You can only book your trip through Concur. Concur is Vanderbilt's online booking tool.** Please note that Vanderbilt will not reimburse a flight purchase outside of the Concur online book tool.
3) For International flights - multileg we recommend that you call World Travel which is the VU travel agency. Phone Number: (877)271-9258
4) Are you considering applying for the travel award from the graduate school? https://gradschool.vanderbilt.edu/gli/gstravel/
5) After your travel, please submit a travel expense report in Oracle. Please follow this link for guidance on how to submit a travel expense report.