Teaching Statement

I consider educating the next generations of engineers, scientists and citizens an honor and an important duty of a faculty member. My goal in teaching is to provide intellectual tools for the students to discover knowledge, develop techniques and more importantly acquire the ability to think independently and critically. This objective overlaps with my research philosophy - to create practical models and engineering solutions driven by scientific discovery, deep insight, and sound judgment. Beyond providing vocational education and training, my teaching approach focuses on encouraging and guiding students to actively seek ways to apply and expand their knowledge in order to create solutions. Since joining Columbia in 2014, I have been teaching both introductory courses for undergraduate students and advanced graduate courses, in which students are exposed to state-of-the-art techniques in the fields of geomechanics and computational mechanics. I have also been actively engaged in providing research training for students at all levels, including high-school students from local, minority serving public schools as well as STEM teachers.

I teach two courses per year in the Civil Engineering and Engineering Mechanics Department at Columbia: CIEN3141 Soil Mechanics (undergraduate, spring), ENME6320 Computational Poromechanics (graduate, even year fall) and CIEN4253 Finite Element in Geotechnical Engineering (graduate, odd year fall).

In the Soil Mechanics course, my objective is to let students develop an understanding of the engineering properties of soils as multi-phase materials, learn and apply basic analytical methods and techniques through exercises, interpret experimental results and conduct basic soil tests. The course begins with a review of linear algebra, calculus and basic concepts of mechanics of solids. This is followed by an introduction to the history of geotechnical engineering and the index and classification of soils. Relationships among the optimal compaction, the degree of saturation, wettability of soils and the retention behavior are additionally explained. The course also covers basic concepts of fluid transport in soils, in particular, Darcy's flow, flow-nets, the concept of the effective permeability of a representative elementary volume of soil, and permeability anisotropy. Meanwhile, special focus is also given to a number of basic concepts of solid mechanics that are critical to geotechnical engineering. In particular, the relationships among principal stress, Mohr's circle, yield surfaces, failure envelopes, stress paths and the cohesive-frictional responses of soils under drained and undrained conditions. After introducing the basic idea of mechanics of materials, the students should be familiar with the relationships between eigenvalues and eigenvectors of stress and the major, immediate and minor principal stresses. They should also be able to understand the relationship between a coordinate system, stress invariants, and the stress components. After the students have developed a sufficient background on both the solid and fluid mechanics required for geotechnical engineering, the course then introduces the concept of the principle of effective stress and the transient consolidation process in Terzaghi's and Biot's poroelasticity frameworks. The course then concludes with a brief review of the essence of the critical state mechanics framework and the Cam-clay model, which allows one to replicate the transition of contractive and dilatative behaviors of soil under drained and undrained conditions. The course covers a lot of fundamental material because it can be the only course in soil mechanics some students take as a result of the breadth requirements for an accredited civil engineering curriculum.

My graduate courses are offered during the fall semester. These courses cover advanced materials concerning the physics, mechanics and computer simulations of porous media and geological material behavior. The Computational Poromechanics course, which is offered in even years, covers the mixed finite element method used to model the hydro-mechanical responses of geo-materials. The mathematical analyses that ensure the solvability, stability, robustness, and accuracy of the models are covered. In the Finite Element in Geotechnical Engineering Course, offered in odd years, the major objective is to enable students to model nonlinear physical phenomena involving path-dependent materials in an implicit finite element framework. I cover topics ranging from solving large-scale nonlinear systems of equations, to return mapping algorithms, to cutting plane methods to the multiplicative group theory and Lie algebra for modeling geological materials undergoing large deformation. In both of those courses, I use the last two

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lectures to highlight the application of the course material the students have mastered to very recent research topics, such as hydraulic fracture, crystallization in pores and the chemo-mechanics of geomaterials. My goal here is to excite and motivate students about emergent topics and the role of research in solving modern day engineering challenges.

My teaching experience also influences my approach advising my Ph.D. students and postdoctoral research scholars. I anticipate that I will graduate one to two Ph.D. students per year. I work very closely with my students and postdoc researchers. However, I am also aware of the importance of striking a balance between helping them solve ongoing issues and providing them with enough space for their own intellectual growth. On a daily basis, I formulate research directions, brainstorm ideas, check derivations, proofread manuscripts, discuss problems, provide feedback, and rehearse their presentations with them. As their advisor, educator and senior colleague, I serve as their role model and try to exemplify the standard I set for my research group and classes with my actions. Since 2014, my research group has graduated three Ph.D. students, Yang Liu and SeonHong Na, and Kun Wang. In all three cases, my students always landed multiple tenure-track or government research laboratory job offers. Yang and SeonHong have already started their tenure-track positions at **Northeastern University** and **McMaster University**, respectively. Both of them are currently in the process of building their own research groups. SeonHong has already secured funding from the Canadian National Research Council on modeling the impacts of climate change on frozen soil, while Yang has recently obtained external funding to create a machine learning algorithm to study ceramic matrix composites. My other Ph.D. student, Kun Wang is now a postdoctoral research scientist position at the Theoretical Division at **Los Alamos National Laboratory.** While my 4th PhD student, Eric Bryant has scheduled his qualification exam in November, and has already obtained multiple interview opportunities from Sandia National Laboratories and Los Alamos National Laboratory. Meanwhile, two of my former my former postdocs have secured positions in academia. Jinhyun Choo joined the **University of Hong Kong** as an assistant professor in 2018, while Chuanqi Liu joined Chinese Academy of Sciences as an associate professor in 2020.

I am very proud of educating and serving PhD students and postdoctoral scholars who are now successful assistant professors, scientists and engineers in their own rights. As my research group members continue to graduate and land tenure-track positions in academia and other high-profile research opportunities, I am confident that my mentorship will help support their ongoing success. Together with my current and former students in academia, national laboratories and industries, we are building a team that may one day have a strong presence in our research community.

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