Project Name: Using ball-and-stick models for mineralogy instruction

Requested Support Amount: $1000

Description: I propose to purchase a 2 mineral “Ball-and-Stick” models (quartz and olivine) from Klinger Education products for use in Department of Geology classes. These models provide hands-on crystal structure models for use in classes that study minerals. These 2 minerals reappear in a large number of important earth and engineered materials. Examination of these models will be performed by students in parallel to using the computer-based modeling software CrystalMaker which has a database of several thousand minerals. This will result in a synergistic effect by maximizing student comprehension of mineralogical concepts by using both physical and virtual models.

Goals: Mineralogy is study of the chemistry, crystal structure, and physical properties of minerals, and includes the processes of mineral origin and formation, classification of minerals, their geographical distribution, as well as their uses in human civilization. This field is critical for understanding Earth processes that range from deep Earth structure and plate tectonics, near-surface process such as soil formation, and the role atmospheric particles in controlling climate and pollution migration. Mineralogy is a key subject taught in classes at all levels within the Department of Geology; CORE introductory courses (How the Earth Works and Environmental Earth Science), undergraduate major courses (Earth Materials I, and Earth Materials II), and upper division/graduate courses (Environmental Mineralogy, and Environmental Geochemistry). This topic is a fundamental component of the successful careers of both our undergraduate and graduate students, and it is critical that they understand how atoms are arranged and bonded to each other in different types of minerals. This can be aided by using physical models referred to as ‘ball-and-stick’ models. We intend to purchase quartz and olivine, two of the most abundant minerals at the surface of the Earth. Properties of substances as related to crystalline structure are easily visualized from these colorful lattice models. The concept of a unit cell, cohesive forces and the meaning of coordination numbers as well as crystal systems can be explained. Models are assembled with wooden spheres 25 mm in diameter, connected by steel rods. The wooden spheres designating the atoms, are painted colors depending on the element represented. Models vary from approximately 18 to 38 cm. in height. The combined price of these two models is $1,010, and the Department of Geology will provide the additional funds to purchase the complete set.

Impacts: Some recent research has aimed to determine if students prefer physical, hands-on crystal structure models (e.g., physical ball-and-stick) or those generated by the computer. This work has specifically aimed to determine if student preference depends on which concepts the models are being used to teach, and if student preference for a particular model type tracks student comprehension as determined by test scores. With respect to student preference and ease of use, Kuo et al. (2004)[1] found that computer models have an advantage over flat or perspective drawings in 2-D, but are perceived by students as more difficult to work with than hands-on models. Kelly (2001)[2] found that students vary in their preference of model types: some like hands-on models while other prefer computer visualizations. With this in mind, the ideal strategy would seem to involve having both types of models on hand if at all possible. With a variety of alternatives on hand, students can make connections between the hands-on and computer models and resolve ambiguities that might arise by being restricted to a single model type. With respect to student achievement and understanding, Jones (1996) tested the use of molecular modeling software versus hand-held models in an introductory chemistry course at the University of Northern Colorado. No difference in student achievement was reported between two groups of students which used different types of models. A common theme of the available research is that different types of structural models can be used to illustrate different concepts. More details of these studies are available through the Science Education Resource Center at Carleton College (http://serc.carleton.edu/index.html).
References: 1. Kuo, M.; Jones, L.; Pulos, S.; Hyslop, R., The relationship of molecular representations, complexity, and orientation to the difficulty of stereochemistry problems. The Chemical Educator 2004, 9, (X), 1-7. 2. Kelly, I. Comparison of Virtual Models and Hands-on Models for Teaching Crystallography. Purdue University, 2001.

Project Activities and Timeline: The ball-and-stick models will be primarily used in the following classes to aid in understanding mineralogical concepts in both lecture and laboratory settings which are key concepts for understanding essentially everything that we discuss in the following courses.

How the Earth Works (Kent science CORE course offered every semester): This course focuses on learning about earth materials (minerals, rocks and water) and understanding fundamental earth processes such as earthquakes and volcanic activities. The entire course is built on the template of the theory of plate tectonics, connecting essentially all geological processes to the effects of the moving tectonic plates. We also look at few economically important Earth materials (coal, different forms of hydrocarbon and other energy related earth material such as uranium) in relatively greater details. Finally we look at the natural mechanisms by which the Earth's climate has been changing throughout its history.

Environmental Earth Science (Kent science CORE course offered every semester): This course focuses on the fundamentals of physical geology (rock types, mineral identification, plate tectonics, etc.), with an emphasis on human interaction with their environment. We explore natural processes and anthropogenic (human-impacted) effects on those processes in the context of natural hazards, natural resources and sustainability. We discuss issues related to human population growth and its impact on the natural world; describe the interactions between tectonic plates and volcanic eruptions and earthquakes; explain the ways that people contribute to and mitigate damage as a result of natural disasters like tsunamis, landslides, and flooding; discuss evidence of global climate change and possible impacts of anthropogenic warming; discuss the coastal processes and ways to prevent erosion; describe appropriate locations for waste disposal; and explain the causes of soil, air and water pollution.

Earth Materials I and II (Geology major course, offered each Fall and Spring, respectively): These courses focus on learning the fundamental concepts of mineralogy, crystallography and the three different rock types, igneous, sedimentary and metamorphic. In Earth Material 1 the students learn basic chemical and crystallographic properties of different minerals and how they form from magma and give rise to different types of igneous rocks in different plate tectonics settings. The first part of Earth Material 2 focuses on the formation of different types of sedimentary rocks in varying surface environments. Later, we focus on the different factors controlling metamorphism and how different mineral assemblages are generated by metamorphism of different protoliths under varying temperature-pressure conditions. Earth Material 1 and 2 are two of the most fundamental courses in the geology program, and are prerequisites for almost all upper division undergraduate geology courses. Environmental Mineralogy (Upper division/graduate course offered every other year): Based on the foundation of mineralogy and (bio)geochemistry, these class explores reactions between minerals and aqueous solutions, including growth and dissolution, surface complexation, and redox reactions. We focus on the role of these reactions in chemical weathering, contaminant transport, microbe-mineral interactions, and an understanding of mineral-water interface processes and mechanisms at the molecular level. Common analytical methods used in mineral-water interface studies are introduced throughout the course. A series of cases studies are placed in a historical and geological context. The underlying mineralogy and (bio)geochemistry of each case study is emphasized. An emphasis is also be placed on the potential role of remediation and the societal impacts of each contaminant.

Communication Plan: Our communication plan involves 1.) announcing the grant awards for the ventilator, capnography system, and critical care supplies through a number of internal media forms, including print and digital media; 2.) participating in the University Teaching Council Conference in Fall 2020; and 3.) seeking other professional opportunities to present our findings from integrating critical care equipment and technology into multiple courses for repeated use by our nursing students and their transition into the nursing profession based on this learning experience.

Evaluation Plan: Successful integration of the ball-and-stick models into course curricula will be evaluated through targeted questions at the completion of the semester to supplement the standard teaching evaluation. These questions will specifically aim to determine if the in-class laboratory activities using the physical model helped to create a deeper understanding of the topics discussed. I anticipate that this evaluation will shift towards more positive responses after these models are used in the course compared to previous semesters when this course was offered. I will also track individual student's success on exam questions that test concepts addressed by using both physical and virtual models. These will be compared to exam questions that test concepts learned with computer models only. In-class and laboratory activities will target both surface (primarily recall) versus deep (problem-solving) learning. I expect that the concepts that were learned with both physical and virtual models will be answered more often correctly than questions on concepts that were learned with only one type of model.

This would indicate which of the project components were most effective. I will also ask our peers to observe and evaluate the engagement of students during lectures and laboratory activities in which both physical and virtual models are used in comparison to previous semesters in which only one model (or none) were used.

Professional Background: At Kent State University, I have taught five different classes, including in the core curriculum, a required course for Geology majors, advanced undergraduate/M.S. level, and M.S./Ph.D. level. One of these classes (Environmental Mineralogy) was newly developed by me, and three were major curricular overhauls (Environmental Earth Science, Earth Materials 1, and Environmental Geochemistry) to meet the needs of our undergraduate and graduate students interested in mineralogy and geochemistry, and to support students working with colleagues in related fields. Each course that I have taught at Kent State University has been reviewed by a full professor in the Department of Geology. These evaluations highlight well-organized lectures, engaged students, a balance between lecturing and discussion, and robust syllabi and teaching materials. Reviews by my colleagues have consistently noted my command of the material and ability to use accessible examples to explain complex concepts. I have incorporated feedback from these evaluations in subsequent semesters. I am proud of the work I have put into creating effective and impactful classroom learning environments. In addition to positive peer, student evaluations routinely reflect my consistent high-level teaching skills. In recognition of my teaching accomplishments, I was awarded the Kent State University Department of Geology's Glen W Frank Outstanding Teaching Award in 2018 and 2019, and the College of Arts and Sciences Distinguished Teacher Award in 2019. I have advised or co-advised one Ph.D. student and three M.S. students to successful degree completion. These former graduate students are all gainfully employed; the Ph.D. student is on faculty at the University of Mississippi, and the M.S. students are working in environmental and energy consulting. I am currently advising two Ph.D. students and 3 M.S. students. All of the former and current students have presented their research at national conferences (e.g. American Chemical Society, Geological Society of America, American Geophysical Union), and three students have had their work published to date. I have advised research experiences for 13 undergraduate students, which includes; two who have gone on to graduate school; two whose work has been published; one NSF summer REU student, and one KSU honors thesis project. I am currently advising four undergraduate students, including a KSU Summer Undergraduate Research Experience (SURE) Fellow. I have also participated in two faculty profession development workshops conducted by the NSF-funded Science Education Resource Center (SERC) program "On The Cutting Edge": (1) "Early Career Geoscience Faculty workshop" (July 2013), in which I participated in sessions on effective teaching strategies, course design, establishing a research program in a new setting, working with research students, balancing professional and personal responsibilities, and time management; and (2) "Pan-African Approaches to Teaching Geoscience" (May 2017) which focused on how Africa is integrally linked to the United States through the impact of Africans in America and Africa as a source of minerals, other materials and intellectual resources. Yet, African-Americans are underrepresented in the geosciences, and attracting African-American students to the geosciences is a challenge.

Spending Plan: Purchasing 2 mineral "ball-and-stick" models for classes that include mineralogy.