PLANETARY SCIENCE IN SCHOOLS USING TABLETOP SCANNING ELECTRON MICROSCOPY

N. Hirakawa[1], M. Hatakeyama[2], L. Warriner[3], Y. Kebukawa[4], A. Nakato[5], and H. G. Changela[6,7*], [1]Department of Education, Osaka Kyoiku University, 4-698-1, Asahigaoka, Kashiwara-shi, Osaka, 582-8582, Japan. [2]Seiko Gakuin High School, 100 Takinoue Naka-ku Yokohama-city, Kanagawa, 231-0837, Japan. [3]St. Paul's School, 80 Lonsdale Road, London, SW13 9JT, England, [4]Graduate School of Engineering Science, Yokohama National University, 79-5 Tokiwadai, Hodogaya-ku, Yokohama 240-8501, Japan. [5]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, 229-8510, Japan. [6]Department of Earth & Planetary Science, University of New Mexico, Albuquerque, NM 87131, New Mexico, USA.[7] J'Heyrovski Institute of Physical Chemistry, Czech Academy of Sciences, Prague, Czech Republic. * changela@unm.edu ; hitesh.changela@jh-inst.cas.cz

Introduction: Placing the next generation of scientists in an environment nurturing further exploration can inspire. By engaging them in hands-on, cutting edge research in their own classroom can this be achieved. Planetary science can provide such a platform. Its interdisciplinary nature supports Science, Technology, Engineering, Arts and Mathematics (STEAM) curricula whilst accelerating the engagement of space exploration to the next generation.

Various exploration missions to asteroids, comets, and satellites are planned and underway. Opportunities to learn about planetary materials and sample return missions have been provided by e.g. space agencies, museums and institutional public lectures [1-3]. However, direct study and project work on planetary materials by school students are less common-place, probably due to the lack of access to laboratory instrumentation. With the miniaturization of certain key techniques such as scanning electron microscopy (SEM) though, schools could be more readily equipped whilst also potentially assisting cutting-edge research in a classroom setting.

Outreach Program: As a case study, two schools in the UK and Japan - St Paul's School, London and Seiko Gakuin High School, Yokohama, respectively - were introduced to planetary science for table top SEM project work on carbonaceous chondrites with relevance to JAXA's *Hayabusa*-2 and NASA's *OSIRIS-ReX* sample return missions. A tabletop Hitachi *TM3030* SEM was provided to Seiko Gakuin by Hitachi High-tech. St Paul's also has a Hitachi *TM3030*. Senior age group secondary and high school students were presented to at St Paul's and remotely to Seiko Gakuin about planetary materials and sample return missions in June 2021. Participants learned the latest achievements by e.g. *Hayabusa*-2 and various techniques used in planetary materials research. In October 2021, additional classes were conducted at Seiko Gakuin with reintroduction to planetary science fundamentals, such as the formation of the Solar System and chondritic components [4], and SEM theory. Afterwards, they observed some chondritic components using an optical microscope. In November 2021 the students with the *TM3030* SEM studied carbonaceous chondrites (Tagish Lake, C2, ungrouped) at Seiko Gakuin and St Paul's (NWA CV3 and CK3-6 thin sections). Students in both schools made montages of the carbonaceous chondrite thin sections and reported features of interest in them, such as cataloging alteration textures. Students in Seiko Gakuin reported their findings at a workshop (International Research for School, 2022) [5].

Outcomes: Direct investigation of carbonaceous chondrites as carbon- and water-rich extraterrestrial samples was impactful, with the students linking their observations with origins of life theories described in the introductory classes. They were trying to classify components by interpreting textures in the thin sections and relating them to the literature. Elemental analysis using e.g. Energy dispersive X-ray spectroscopy attached to the tabletops could support further characterisation and learning goals in e.g. natural science, geology and chemistry. SEM theory is highly applicable for Advanced Level physics syllabuses, (e.g. electric and magnetic fields concepts, quantum theory and mechanical materials). With further experimental design and lesson planning with teachers, classes could also be guided to assist with direct planetary materials research. Uncharacterised meteoritic samples are examples for further study. As well as meteorites, *Hayabusa*-2 samples (and *OSIRIS ReX* in 2023-2024) samples could engage students in the cutting edge planetary materials research by careful planning and coordination between schools using the tabletop SEM. The portability of tabletop SEMs also opens up avenues for sharing a tabletop between multiple school laboratories. Ultimately, by placing the students in a global framework in similar fashion with space borne missions, can the next generation of scientists work towards common goals internationally, and evaluate modern space exploration. Further work is required to design such a coordinated international program for schools.

References: [1] Welzenbach L. C. and Corrigan C. M. (2010) 73rd MetSoc, Abstract #5350. [2] Madiedo J. M. (2012) EPSC 2012, Abstract, 7 EPSC2012-8 2012. [3] Hutson M. L. et al. (2015) 46th LPSC, Abstract #1690. [4] Russell S.S. (2018) Elements, 14, 113–118. [5] Hirakawa N. et al. (2022) GeoSciEd IX, Abstract.