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Microscopy and Team-based Interdisciplinary Materials Research to Achieve 21st Century Skills

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The Education and Outreach (EO) program is an essential part of the National Science Foundation funded Materials Research Science and Engineering Centers (MRSEC) program. The Center for Research on Interface Structures and Phenomena (CRISP) is a MRSEC housed at Yale and Southern Connecticut State University (SCSU). The overarching goal of CRISP EO is to use interdisciplinary science (e.g. materials science) as a vehicle for enhancing the education of future scientists, educators, K-12 students, parents and the general public. The educational goals and resulting signature programs were designed to optimize integration of the research and educational strengths of CRISP through high impact EO activities. One such program is the MRSEC Initiative for Multidisciplinary Education and Research (MIMER) [1]. The MIMER program provides opportunities for team-based interdisciplinary research experiences to students and teachers by integrating the CRISP research experiences for undergraduates (REU), teachers (RET) and high school fellowship programs. A MIMER team assembles researchers with different backgrounds including a faculty member/CRISP researcher, graduate students and/or post-docs, undergraduates, teachers and high school students. The collaborative and interdisciplinary nature of the MIMER team encourages synergy and fosters the formation of mentoring relationships among team members.

The collaboration between the CRISP REU and the SCSU departments began in 2006 when CRISP hosted several high school and undergraduate students participating in the NASA Goddard Institute for Space Studies New York City Research Initiative (NYCRI) program led by Dr. Frank Scalzo. These students joined the REU and RET participants forming a team that was co-mentored by SCSU professors John DaPonte (Computer Science) and Christine Broadbridge (Physics). The framework for this collaboration was the utilization of image processing to address materials science and nanotechnology research questions by studying the processing/structure/property relationships. A variety of microscopy techniques were used including scanning electron, transmission and atomic force microscopy.

There is an acute and well-documented need for image processing of microscopy data in materials science regarding, for example, the characterization of the structure/property relationship of a given materials system. For these MIMER teams, image processing was used as a framework for conducting interdisciplinary team-based research that effectively integrates programs within the CRISP MRSEC, while also successfully achieving the infusion of 21st Century Skills. These skills are often classified according to categories including: *ways of thinking* (creativity, critical thinking, problem solving, decision making, learning, scientific reasoning); *ways of working* (collaboration, communication); *tools for working* (information and communication technology, information literacy); and *skills for living in the world* (citizenship, life and career, personal and social responsibility) [2, 3, 4]. Survey data indicates

that students in the CRISP MIMER program benefit from achieving these skills while also gaining detailed knowledge regarding the fundamentals of materials science and nanotechnology.

It is well understood that unique properties often associated with nanomaterials are highly dependent upon physical characteristics, including, for example, nanoparticle size (diameter) and size distribution. Typically, these parameters are obtained by manually measuring and counting particles within a digitized microscopy image, a task that is highly laborious and subjective. The goal of the work was the development of a methodology based upon a computer implemented particle analysis to measure objects in a binary image using a more objective and consistent definition of a particle [5]. All steps in this process were performed using the open-source image analysis suite ImageJ [6,7].

For this presentation a review of selective collaborative microscopy and image processing projects completed under the MIMER program will be presented [8]. The common motivation was to address the need for computer-aided image analysis of nano-characterization data by developing and implementing an automated, objective, global image processing routine. An account of the progression of research throughout the program will be discussed [9]. Initial work began with analyzing microscopy images of well-defined systems (i.e. spherical particles) in order to establish the routine/methodology for image processing. As new methods evolved, progress enabled work on more challenging material systems. This concept was applied to a variety of systems ranging from nanoparticle size distributions to frequency and pore size in cortical bone. The most recent research project aimed to adapt the particle analysis routine to a system composed of nanowires on polymer substrates.

MIMER teams inspired by a variety of other materials science and nanotechnology research problems joined the MIMER image processing teams. This presentation will also include a general overview of the CRISP MIMER program, a discussion of some of the beneficial impacts as well as lessons learned. For example, pre/post and retrospective REU student survey data will be presented revealing the possible role that collaborative student research experiences play in the development of 21st Century Skills. These preliminary results support the notion that collaborative student research experiences offer students meaningful interdisciplinary benefits and these experiences better prepare students for graduate school and careers in science and engineering fields [10].

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