Team-based, Transdisciplinary, and Inclusive Practices for Undergraduate Research

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***Abstract*—We present work-in-progress reflecting on the initial year of a distinctive summer Research Experiences for Undergraduates (REU) program. Our REU model combines fundamental research in computational sensing with a scholarly context that connects computer science with computational liberal arts. Students are intellectually stimulated to make sense of people's behaviors and cognitive processes with multimodal sensing hardware and software. In doing so, they explore the fundamental challenges found at the intersection of computing, the human experience, and scientific interrogation. The placement of the human experience at the core of the research theme enables an environment that stimulates and cultivates an innovative undergraduate research model. We highlight outcomes from the first year and discuss three emerging practices that are central to our REU framework: (1) team-based collaborative training; (2) transdisciplinary integration; and (3) systematic prioritization of inclusiveness. We also describe how these practices are incorporated into our overall undergraduate research framework and touch upon lessons learned from feedback collected.**

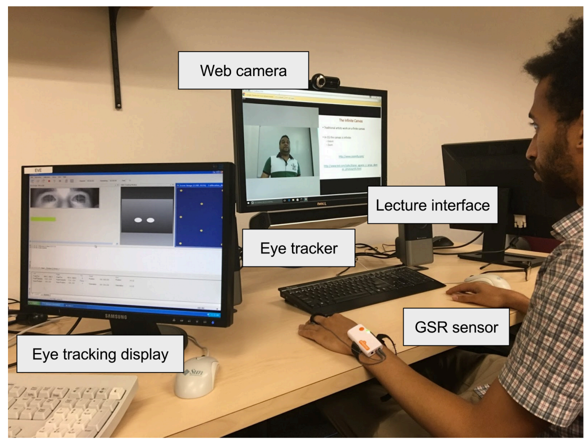

Fig. 1: Example of a multimodal data collection scenario from one of the REU projects exploring cognitive reactions with respect to web-based learning.

I. Introduction

We report on an emerging undergraduate research framework from the NSF Research Experiences for Undergraduate (REU) Site in Computational Sensing at Rochester Institute of Technology. Unobtrusive observation of people's physiological, behavioral, cognitive, and environmental data is increasingly enabling new computing experiences. This REU Site recognizes the accumulating need for training emerging researchers to gain experience in and grapple with systematic collection, processing, analysis, and interpretation of heterogeneous human-elicited information. Instead of merely leveraging traditional physiological measurements, our research program takes a holistic approach to the capture and integration of such sensing data. For instance, the data may also include linguistic and eye movement behaviors, or social and geospatial contextual information. These modalities provide rich information. An example of a multimodal data collection scenario from a project in the REU Site's first year is in Figure 1. This project applied sensing for observing and measuring cognitive reactions as participants engaged in tasks involving web-based video lecturing.

While computational sensing research is growing, these data are complex, making it necessary to extend beyond traditional computer science training and embrace collaborative team science across disciplines. The Site makes the transdisciplinary research theme a priority, which bridges and blends computational science with computing-focused liberal arts. The next generation of scientists can benefit from being trained to combine methodologies and analysis tools in creative ways, and to intellectually leverage complementary and opposing perspectives. Central to the REU program is a set of career-enhancing professional development activities that aim to infuse the experience with important life skills such as the fostering of communicative excellence and intellectual agility, cultivating critical thinking, as well as nurturing societal responsibility and peer interactions.

II. Intellectual Focus

As shown in Figure 2, the REU Site addresses topics of importance for the computational sensing community. One such research challenge is the *acquisition* of multisource human data – how to collect, synchronize, filter, process, and validate multifaceted data. Another research challenge is their computational *fusion* [1], [2], [3]. These intellectual themes further allow participants to explore the role of contextual factors, such as experimental design, modality types, human variation, and domains of *applications*. The practical side

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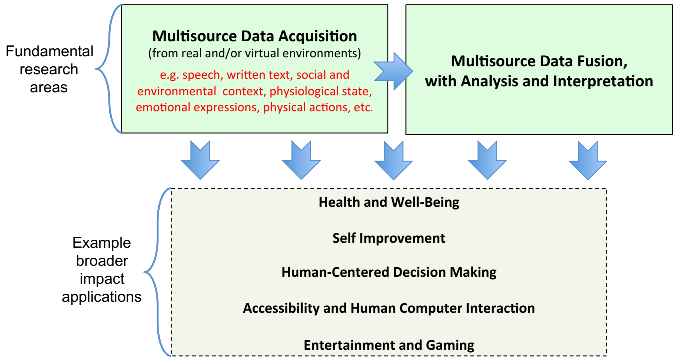

Fig. 2: Focus areas of research and applications in the REU Site in Computational Sensing.

helps articulate social contributions and keep project objectives concrete for the undergraduate researchers.

Each summer, our REU Site coordinates five project teams. Teams in the first year of the program pursued a variety of research directions within the Site themes, such as:

- One team investigated computationally measuring viewers' behaviors as they viewed a video lecture, with the long-term goal of enhancing online education outcomes. Results included (1) the development of an innovative study methodology for computationally linking learning and attention; (2) insights into how the difficulty level of course materials can impact human measurable behavior; and (3) improved understanding of the challenges involved in capturing natural multisource human data and recommendations for addressing these issues.
- Another team investigated how readers interpret, perceive, and react to narrated experiences involving (or not involving) interpersonal violence. Readers' text annotations of stakeholder roles and emotions were co-collected with galvanic skin response, pulse, and facial expressions. Results included (1) insights into how readers process semantic roles and emotion in the narratives; (2) new understanding of how measurement-based data can support text annotation; and (3) a method for mapping between outputs from human and automated annotations.
- A third team addressed computationally mapping where people look in an image to what they say about it and their corresponding facial expressions, with automatic labeling of image regions as a key application. Contributions included (1) advancement of an experimental methodology for co-capturing multisource data with observers viewing and responding to description-oriented vs. affect-oriented questions about images; (2) extension of a multimodal bitext alignment approach that creates meaningful pairings between narrated observations of images and image regions indicated by eye movements [4]; and (3) exploration of how observers' verbal or facial responses link to the valence of an image and prompt type.

Three peer-reviewed team publications have resulted from these projects [5], [6], [7].

III. REU Program Structure

The mentoring framework of this REU Site is designed to promote T-shaped training of undergraduate students [8], where breadth and depth of research are integrated and emphasized. Specifically, the mentoring model seeks to:

1) promote a student-centered teacher-scholar approach to team research [9], [10],
2) motivate mentees with level-appropriate active learning [11];
3) progressively develop students' research tasks, assignments, and independence [12];
4) hone disciplinary knowledge while cultivating fundamental research skills and applied critical thinking; and
5) prioritize diversity excellence and emphasize its potential for enabling innovative thinking.

The left-most column of Figure 3 outlines the general progression of each student/team through the research process. The rest of the figure lists key students deliverables as well as parallel formative activities for the students. Based on our experience and feedback from the initial year, going forward these activities are being front-loaded in the earlier weeks of the program to allow students more time to focus on data analysis, interpretation, and dissemination of results toward the end of the program. This aims to improve the pacing of the 10-week investigatory cycle. Another planned improvement includes a week-by-week, mentor-approved time plan of activities submitted by students in week 2; this plan is expected to be continuously refined as projects evolve.

In addition to the research projects, our program offers its participants a comprehensive set of career-enhancing professional development activities, including the following:

- Web-based training and a workshop on human subjects research.
- A noncredit seminar course, *Toward Graduate Studies*, with planned topics for the second year seen in the

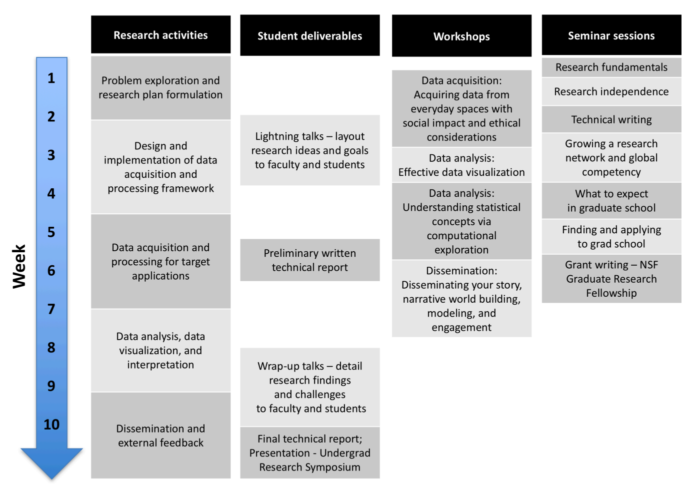

Fig. 3: Formative progression of principal training elements of the REU Site in Computational Sensing including research process and other key activities and deliverables.

last column in Figure 3. The seminar format is flexible – enabling the incorporation of presentations by REU students or invited panels of graduate students, etc. One panel from our initial year involved recipients of NSF Graduate Research Fellowships.

- A journal club discussing technical articles and elements of scientific reporting: effective introductions, informative visuals, components of an article, research writings (meta-reviews, research papers, opinion pieces), etc.
- A field trip to a research lab where students interact with professional researchers and gain insight into research from an industry perspective.
- Team-building cohort activities such as field trips and social events.
- Coordinated activities and exchange of best practices among local REU programs, including a co-organized symposium on graduate study and research.
- Post-program video conference follow-up for reconnecting the cohort, sharing updates on opportunities at students' home institutions, discussing students' future plans and how REU leadership can support them, etc.

Internal Site communication is important. Our REU Site leverages these mechanisms:

- A website with information such as Site focus, important dates, links to recruitment and application materials, research mentors, project abstracts, workshop titles and abstracts, and a list of programmatic activities.
- A web calendar, kept up-to-date about programmatic activities, due dates, and team-building social activities.
- A Site-internal Facebook group, used to share photos and reminders of weekly activities, and to stay in touch after the program.
- Team email handles to simplify team-internal correspondence.
- Cloud-based drives for uses such as teams' shared recordkeeping, journal club readings, faculty materials, and logistical materials.
- Web-based interaction tools facilitating continued post-program collaborative work, including for technical report writing, or for team and cohort meetings.

IV. Strategies To Support The Student Research Framework

Three emerging central practices of our undergraduate research framework are discussed below.

A. Team-based Collaborative Training

The Site uses a systematic approach to team formation for advancing computer science problems and STEM research training. The Site pairs students on research teams where they are jointly mentored by at least two faculty research mentors. Graduate students are encouraged to serve as co-mentors and in doing so gain mentoring experience. The pairing of students encourages a co-learning context, where initially students can work closely together and then, as the work advances, diverge into individual data processing, analysis, and interpretation efforts. This design thus naturally nurtures increased independence in research activities. Moreover, our program seeks to stimulate pre-arrival interaction in teams. Examples include guidance on preparatory readings and research-relevant trainings and certifications that are required or optional. While the main objective of pre-program tasks is to help students prepare for their program experience, with reasonable time commitment, it can also help connect students early. Once the program begins, regular team meetings are scheduled. Program organizers provide complementary mentoring support.

The program incorporates two types of structured feedback activities with mentors:

1) *Mentor reports*: Each student is assessed three times using a mentor report form with ratings and narrative feedback. The form includes questions about the student's ability to find, read, filter, and apply technical information to their specific project, their willingness to take initiative, their capability of formulating research questions, their ability to deploy sound methodological practices when setting up experimental work, their problem solving and creative skills, their capability of linking theory with empirical work, and their time management and presentation skills, etc. Students receive the completed mentor reports. The feedback occasions are distributed over the program to provide continuous feedback. In the faculty end survey from our initial year, 90% of responding mentors indicated that the mentor reports involved *an acceptable amount of effort*.
2) *Mentor presentation evaluations*: Students present formal talks twice in the program: lightning talks laying out research ideas and objectives early in the program, and achievement talks toward the end. Mentors are present for these talks and provide feedback to the students with an evaluation form. The program ends with students disseminating work at a campus-wide undergraduate research symposium, followed by a celebration dinner. By scheduling the achievement talks before the symposium, students have an opportunity to incorporate feedback for their public poster or oral symposium presentations.

An additional aspect of the team-based projects is their relation to practicable, real-world application domains, which can impact other disciplines and society. In our first year, these domains included: education and web-based learning, health and wellness, games for education, and image analysis.

B. Transdisciplinary Integration

We also promote team-formation that nurtures thinking across the disciplines to expose trainees to transformative computational research. Teams of mentors are assembled from different academic departments and represent complementary areas of expertise. Further, almost all teams engage mentors from different colleges. The members of a mentoring team work together to formulate a project description as well as the pre-program activities for their students to complete.

Our second year planning resulted in adding a *from-teaching-to-mentoring bridge* as part of the orientation days.

Computational sensing	"many students were able to link concepts based on sensing technology with the ways in which computers can collect data about and adjust to human characteristics."
Collaborative team research	"several [students] commented that the interdisciplinary teams were enriching to their experience."
Transdisciplinary research	"[a]nalysis revealed that all students defined transdisciplinary research as either working with researchers from other fields, or working on research projects using the knowledge from different fields."
Diversity in research	"students felt that among peers, mentors and other collaborators in a research environment diversity was an important component" and "100% [...] of students indicated that diversity among peers, mentors and other collaborators in a research environment was *very important* or *important*."

Table 1: Quotes from external evaluator report commenting on our program's intellectual focus and emerging practices.

The main objective of this mechanism is to help students transition from being taught to being mentored. This is a series of short lectures by faculty mentors that provides initial insights on topics intersecting with the Site focus. It also gives students an early overview of how disciplines complement and are integrated with each other. Faculty can also use their session to share about their own background and path as a researcher with the REU students.

Additionally, the program's schedule of professional development activities aims to build essential life and academic capabilities. Many are associated with training in liberal arts and sciences, such as communication skills, scientific and computational reasoning, coupling social impact and critical thinking with problem-solving competence, and exposure to globally relevant topics. Such abilities benefit students in their continued professional and research careers and contribute to institutional and research community development.

C. Systematic Prioritization of Inclusiveness

We employ thoughtful recruitment, selection, and organizational processes that effectively prioritizes team diversity. This also helps promote awareness and appreciation of the importance of diversity in research among students.

Our recruitment seeks out groups underrepresented in computer science, including women, individuals with disabilities, African American, Latino American, and Native American (AALANA), gender minorities and members of the LGTBQ community. This also includes efforts to channel program information to institutions where students have less opportunity for computer science research. In addition to sending recruitment emails and program announcements to organizations or professionals serving these groups, we advertise on websites and social media and ask colleagues to share information about the program among their networks. We also conduct a hands-on exhibit at a major university festival that annually attracts a large number of community visitors to the campus. As applications arrive, some degree of monitoring is done to determine if we were successfully recruiting across geographic regions, allowing for targeted outreach to institutions from areas of the country lacking evidence of applications. We plan to refine and formalize this approach as part of our overall recruitment process in subsequent years. Further, we boost the number of complete applications by reminding applicants about missing materials on repeated occasions.

After our first year, the Site has adopted a two-stage selection process in which female and male applicants are considered separately and diversity is made an explicit priority. In the first stage, a pre-selection committee individually scores candidates based on submitted academic materials, personal statement, and letters of recommendation. Next, the pre-selection committee deliberates, also considering a range of diversity factors. These include arriving at a balanced ratio of female and male students, focusing on students from institutions with limited access to research opportunities in computing, underrepresented students (first generation college students, ethnic minorities, students experiencing a disability, etc.), and also including students from years earlier than college junior. The committee selects twice as many applicants as there are positions for further consideration and makes a preliminary assignment of candidates to project teams. In the next stage, candidates are interviewed using video conference, inviting input from the faculty mentors they would potentially be working with. A final ranking of male and female candidates is made with input from the faculty mentors. Offers are made to one female and one male student per project team.

Similarly, attention to diversity among faculty mentors and workshop facilitators helps to model the importance of diversity and inclusiveness. Faculty mentors with international background also help alert participants to the importance of global perspectives and international competency.

V. Conclusion

Our first year made progress on implementing a framework for undergraduate research. This paper discussed three principles of this framework. Evaluation from an independent external evaluator included data collected from student pre- and post-surveys, a student focus group, and faculty mentor post-surveys. Table I quotes feedback received from this external evaluation, relevant to these principles, validating the usefulness of the emerging framework. This feedback has also been instrumental for planning refinements for subsequent program years, which will be similarly formally evaluated.

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