

Improving Undergraduate Research Mentoring Practices: Faculty Development to Support Non-Traditional Students in Computing Research

Sarah Hug

Colorado Evaluation & Research Consulting
Westminster, USA
0000-0001-6531-0745

Patricia Morreale

Department of Computer Science
Kean University
Union, USA
0000-0002-7954-2122

Heather Thiry

Ethnography & Evaluation Research
University of Colorado, Boulder
Boulder, USA
0000-0003-4444-1855

Abstract— Utilizing the Affinity Research Group (ARG) model, the Computing Alliance of Hispanic Serving Institutions (CAHSI) has provided training for faculty and student research experiences for decades. ARG, a CAHSI signature practice, focuses on deliberate, structured faculty and student research, with accompanying technical, communication, and professional skills development. In the latest iterations that have spanned the pandemic and its recovery, CAHSI has iterated on a virtual training and support network for faculty and students interested in broadening the participation of Hispanic undergraduate students in computer science, to increase the number of Hispanics who move on to graduate studies in the field. This work-in-progress paper analyzes shifting support structures during a multi-year effort to promote undergraduate research development using the Affinity Research Group (ARG) model.

As CAHSI grows to include research-intensive universities that have recently reached the 25% Hispanic enrollment threshold, the faculty mentor training has evolved to emphasize growth mindset and asset-based frameworks for working with undergraduate students in research, particularly important in computing departments which graduate students are more commonly engaged in research. The paper describes areas of need as the populations of faculty and students shift. It addresses the questions : R1) How do faculty engaged in the LREU shift perspectives regarding a) student selection for research, b) pedagogical purposes of research for student development, and c) their ability to implement ARG? R2) To what extent do designed elements of the LREU professional development inform faculty practice and faculty perspectives regarding undergraduate research?

Keywords—faculty professional development, research experiences for undergraduates, cognitive apprenticeship, Hispanic Serving Institutions

I. INTRODUCTION

The Computing Alliance of Hispanic Serving Institutions was recently funded to support diverse students, particularly Hispanic students, to attend graduate school. As part of this most recent grant, the alliance expanded access to

undergraduate research opportunities across member institutions. Faculty and students are funded to participate in research activities either at their home institutions or with faculty virtually. Professional development activities were designed and implemented to support faculty in their work mentoring undergraduates with varied experience in computing at the time of the research experience. In this paper, we analyze the model of training and support with the lens of cognitive apprenticeship, and describe faculty growth through their participation in the Local REU training and development model.

A. Undergraduate Research

Social science research in engineering and related science fields indicates that undergraduate research experiences support student learning, create opportunities for the application of technical science knowledge, develop student identities as creators of new knowledge, and develop communicative and collaborative skills useful in the workforce as well as in the science or engineering laboratory [1, 2, 3, 4, 5, 6]. Prior work has highlighted the importance of mentoring for student success [7] Some studies suggest that students who are underrepresented in STEM may experience a greater boost from participating in undergraduate research, particularly because it can create stronger relationships with faculty they may not otherwise develop [8,9,10], and may increase the recognition they receive from others regarding their abilities in the fields, which research has linked to positive science identity development [2]. The local research experience for undergraduates (LREU) program was designed particularly to improve the number of women, Hispanics, black, and African American students who receive opportunities to do research in undergraduate studies to retain students in the fields as well as to promote aspirations for graduate studies.

B. Affinity Research Group Model

While undergraduate research is known to promote STEM learning for undergraduates, faculty may be reticent to mentor undergraduate students because of the perceived heavy workload in supporting less advanced professionals in the lab

setting. Research from faculty perspectives indicates that a lack of time, lack of money to fund students, and a lack of formal and informal recognition for working with undergraduate researchers are barriers to faculty mentoring of undergraduates [11]. The Affinity Research Group (ARG) model is a promising practice [12, 13] for supporting multilevel teams with an *affinity* for a given topic or research area. Originally developed in the 1990s at the University of Texas at El Paso, the model extends research to a wider spectrum of students by deliberately developing skills supported with collaborative learning [14]. In this paper we suggest the training of faculty to use the ARG model with undergraduate students involves a form of cognitive apprenticeship [15] in which experts in undergraduate research mentoring share their practices, instructional approaches, and specialized ways of thinking with faculty just beginning to mentor undergraduates in research pursuits.

C. Cognitive Apprenticeship Approach

The cognitive apprenticeship approach to teaching and learning draws on situative learning theories [16] that ascribe to a social means of learning through interactive engagement with artifacts, tools, and other people. In cognitive apprenticeship, learners engage with a more expert thinker in a specific field or domain. The more expert individual shares expert thinking through dialogue, resource sharing, lesson planning, and verbal reflection with learners. Learners can observe expert problem-solving practices as the more knowledgeable other individual models that behavior and thinks aloud to provide access to thinking processes he or she is using in the domain of interest [17].

While cognitive apprenticeship has been used to describe mentoring practices of faculty in REUs [18, 19], it has yet to be used to consider faculty learning to mentor their undergraduate researchers. Minschew, et al. indicate the cognitive apprenticeship theory of learning could be useful for considering program development, advising researchers, creating a positive learning environment for research practice [20]. In the LREU, the concepts of scaffolding, making expert thinking visible, and practicing skills in applied settings were relevant and novel to the professional development approach used to support STEM faculty in their mentoring of undergraduate students. We describe this in detail in the “description of the professional development under study” section.

II. METHODOLOGY

A. Description of the professional development under study

The faculty participating in the study were matched with undergraduate students for 8-10 weeks of local REU experience (LREU). Similar to the national REU experiences, where students from undergraduate school visit faculty researchers at other schools during summer to work in-residence at the faculty university, the LREU students were expected to participate in research under faculty direction. Understanding that many students cannot relocate for 8-10 weeks due to other commitments, including part-time jobs or family responsibilities, the LREU did not have a residential

aspect. LREU students remained in their primary residences and conducted research without traveling away from their home campus. Some LREU students were paired with researchers elsewhere in the USA, and remotely mentored, while other LREU students were mentored in person, “face-to-face”.

The local REU supported faculty who may or may not have mentored undergraduate students in the past through the following mechanisms: an orientation to the program, access to resources that covered multiple research- oriented topics, mean to be used by mentors with their proteges. *The resources made expert thinking visible by queuing faculty mentors to the topics to be covered in explicit ways with students in the program.*

In 2022, the ARG model was used with a cohort of faculty who met virtually once as a group, and then received a weekly ARG topic email, which also included ARG materials to be used with the LREU students as the faculty mentors wished. Students were expected to maintain an online research journal, which would be updated weekly by the students, with corresponding weekly feedback from the faculty mentors. The goal was the deliberate development of research skills through skill modeling by faculty and use of the skills by students. *Research journals made thinking visible and encouraged reflection through specific prompts. Students then received feedback from faculty on their thinking via journal comments.*

In 2023, the ARG model was used with a cohort of 53 faculty, and the delivery method was adjusted. As in 2022, there was an initial virtual kickoff meeting of the faculty which provided an overview of the LREU experience and outlined the goals and objectives of the project. For the next eight weeks, the 2023 faculty cohort met regularly, virtually, as a group. Each faculty member was expected to attend one weekly session. The ARG facilitators provided an evening and morning session to accommodate the faculty participants’ four time zones. It was expected that the faculty could arrange to attend one of the weekly sessions, given the choices offered. During the virtual weekly meetings, the faculty introduced and discussed one ARG skill. *As the ‘first learners’, faculty participated by applying the skills they hoped to model for research students in their own research training sessions.*

Active learning exercises were used to reinforce the skill, and the materials the faculty could use with their students were provided in a faculty-only area of project resources. Faculty questions and concerns were discussed, and three facilitators rotated session management. *The faculty development sessions were designed as models of faculty engagements with youth*

In both 2022 and 2023, the skills and materials provided to the faculty remained the same. Faculty were taken through research plan development, including abstract writing, probing questions, constructive critique, elevator speeches, and reflection [12, 13] with the goal of developing a final research poster for their students to present at a conference in early fall.

B. Description of Data Collection and Analysis Practices

This paper is part of a multimethod case study being conducted, using interviews, survey, and artifacts of practice to address the following two questions: RQ1) How do faculty engaged in the LREU shift perspectives regarding a) student selection for research, b) pedagogical purposes of research for student development, and c) their ability to implement ARG? And RQ2) To what extent do designed elements of the LREU PD inform faculty practice and faculty perspectives regarding undergraduate research? This paper focuses explicitly on the survey data pre post from faculty.

To assess mentors' knowledge of effective practices for mentoring diverse students using the Affinity Research Group (ARG) model [12], a pre-post survey was administered in the spring 2022. Additional data collection occurred in the spring 2023 semester. The survey contained several questions related to mentors' knowledge of how to be an effective research mentor and their use of professional development practices within their research groups. The post-survey also asked mentors to select the top three gains of their research students from the experience. The survey was administered electronically to all faculty who had signed up to be a mentor for the CAHSI Local REU program. In all, 23 faculty completed the pre-survey and 21 faculty completed the post-survey.

Quantitative survey data were analyzed using descriptive statistics within each dataset pre and post. Comparisons were made by comparing scale mean scores using unpaired t-tests, as pre and post-surveys could not be matched for the entire dataset. Qualitative survey data, specifically answers to open-ended items, were open-coded for meaning based on the authors' extensive background in the ARG model. For example, codes for defining the ARG model in the pre and post came from main elements of the ARG known to the authors.

III. RESULTS

A. Description of Participants

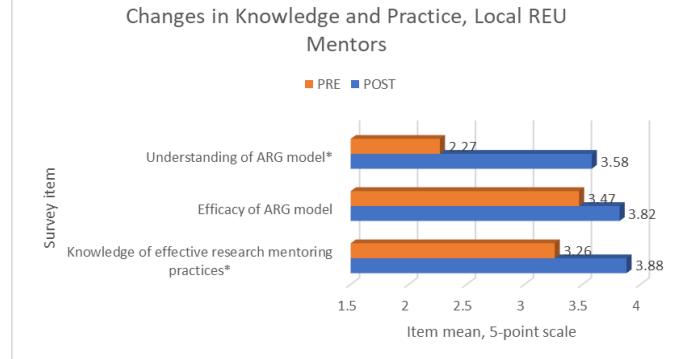
Most mentors (92%) had prior experience in advising or working with undergraduate researchers and 22% of mentors had over 10 years of previous experience in mentoring undergraduate researchers. However, most (52%) of Local REU faculty had one to four years of research mentoring experience. Corresponding to many faculty having had only a few years of experience in research mentoring, the most common local REU faculty career position was assistant professor (44%). Associate professors (28%) and full Professors (22%) were also well represented. Most Local REU faculty (94%) were in tenured positions and had prior research mentoring experience; about 25% of the faculty had used the ARG model in their research groups prior to the Local REU program.

B. RQ 1- Changes in Faculty Perspectives

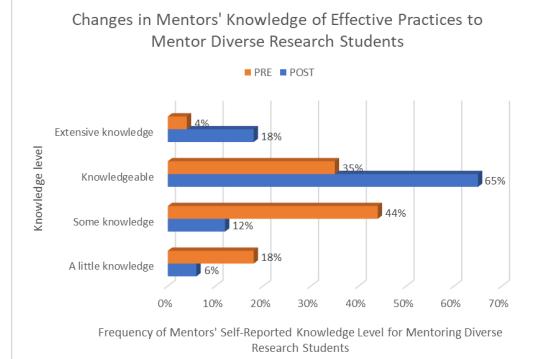
1) Mentors' Gained Knowledge of Effective Research Mentoring Practices and the ARG Model

Local REU mentors are reporting gains in knowledge about how to mentor students from underrepresented groups

and how to effectively employ the Affinity Research Group model in their research groups. In fact, mentors display significant growth from pre- to post in their knowledge of effective research mentoring practices ($t=-2.259$, $df=38$, $p=.030$) and their understanding of the ARG model ($t=-3.639$, $df=37$, $p<.001$). Mentors began the REU with a strong belief in the efficacy of the ARG model for mentoring research students, although their beliefs about the model's efficacy still increased over the course of the REU experience. The figure below outlines the item means on the pre- and post-survey for items related to research mentoring knowledge and skills.



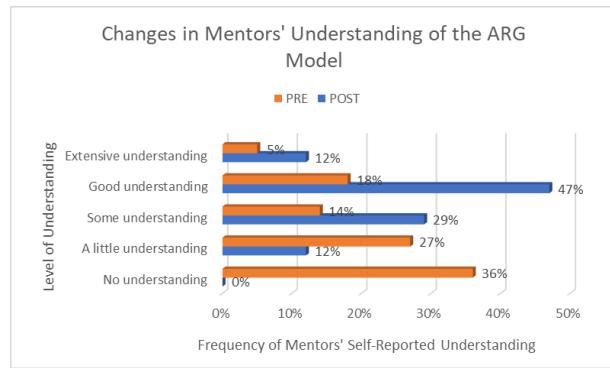
The percentage of mentors who reported being knowledgeable or had extensive knowledge of effective practices for underrepresented students rose from 39% prior to the REU to 83% at the end of the experience. Likewise, the percentage of mentors who only had "some" or "a little knowledge" in this area declined. Therefore, almost all mentors reported strong gains in their ability to mentor research students from diverse backgrounds.



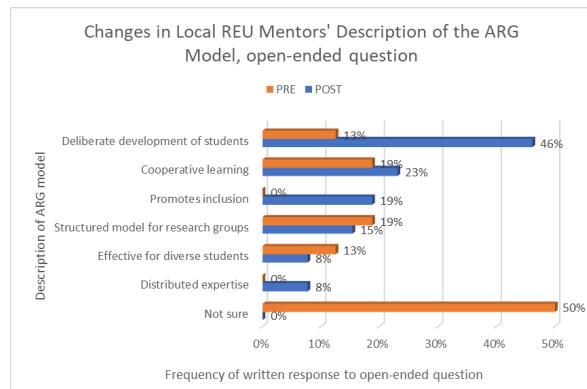
2) Mentors Gained Understanding and Experience in the ARG Model

Mentors gained substantive understanding of the underlying framework of the ARG model and how to implement it in practice. Local REU mentors entered the experience with limited understanding of the ARG model; 63% reported "little" or "understanding" of the model. At the end of the experience, 88% of the mentors reported at least some understanding of the model. The percentage of mentors who reported "good" or "extensive" understanding of the ARG model increased from 23% to 59%. Therefore, local

REU mentors reported significant growth in their knowledge of the ARG model for research groups.



Local REU mentors demonstrated their growth in understanding of the ARG model in their response to an open-ended question that asked survey respondents to describe the ARG model. This question was on both the pre-survey and post-survey. On the pre-survey, 50% of respondents were unable to describe the model and stated that they did not know what it is. On the post-survey, all respondents were able to describe at least some aspects of the ARG model. On the post-survey, mentors were more likely to state that the model fostered inclusion. They were also more likely to note that the ARG model focuses on the deliberate development of students' research and professional knowledge and skills. Further, mentors' descriptions of the model on the pre-survey were general and vague, and were much more detailed and specific on the post-survey, highlighting specific components of the model, such as the distribution of expertise across the research group.



At the end of the REU, mentors offered detailed and descriptive understanding of the ARG model. Following are typical written comments on the post-survey.

The Affinity Research Group Model is a set of practices built on a cooperative team framework to support the creation and maintenance of dynamic and inclusive research groups.

ARG models uses structured activities supported by a team effort to create an engaging and inclusive environment for students to maximize their learning and experiences through their research projects.

IV. DISCUSSION AND NEXT STEPS

Our study of the professional development for undergraduate research mentors found distinct growth in self-reported understanding of the ARG model, values related to asset-based work with undergraduates in a developmental research experience that scaffolds understanding of how to be a researcher.

Evidence suggests utilizing a cognitive apprenticeship model in the professional development of mentors can support faculty in their work with novice undergraduate researchers to build student support structures in their research work. Through intentional modeling of skills to be addressed in the research experience, faculty in the professional development experience a lesson they might then incorporate into their interactions with students.

As we continue analysis on this project, we will develop codebooks that build from related work on growth mindsets [22, 23] to apply to written documentation from mentors as they report on their progress with students, looking for shifts in language towards growth mindset and asset-focused feedback provided to undergraduate researchers. We estimate another 20 responses in spring 2023, which will extend the robustness of our quantitative findings and potentially add statistical power for statistical comparisons of faculty growth pre to post, and across the two training models, with the most recent including more frequent synchronous check-ins with faculty.

V. ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation under Grant No. 2137791

- [1] Atkins, Kaitlyn, Bryan M. Dougan, Michelle S. Dromgold-Sermen, Hannah Potter, Viji Sathy, and A. T. Panter. "'Looking at Myself in the Future': how mentoring shapes scientific identity for STEM students from underrepresented groups." *International Journal of STEM Education* 7 (2020): 1-15.
- [2] Auchincloss, Lisa Corwin, Sandra L. Laursen, Janet L. Branchaw, Kevin Eagan, Mark Graham, David I. Hanauer, Gwendolyn Lawrie et al. "Assessment of course-based undergraduate research experiences: a meeting report." (2014): 29-40.
- [3] Beckman, M., & Hensel, N. (2009). Making explicit the implicit: Defining undergraduate research. *CUR Quarterly*, 29(4), 40-44.
- [4] Corwin, L. A., Graham, M. J., & Dolan, E. L. (2015). Modeling course-based undergraduate research experiences: An agenda for future research and evaluation. *CBE—Life Sciences Education*, 14(1), es1.
- [5] Hunter, A. B., Laursen, S. L., & Seymour, E. (2007). Becoming a scientist: The role of undergraduate research in students' cognitive, personal, and professional development. *Science education*, 91(1), 36-74.
- [6] Pierrickos, O., Beam, T. K., Constantz, J., Johri, A., & Anderson, R. (2009, October). On the development of a professional identity: Engineering persists vs engineering switchers. In *2009 39th IEEE Frontiers in Education Conference* (pp. 1-6). IEEE.

[7] S. Dos Santos, A. Carvalho, G. Leite, L. Brito and A. Gouveia, "Stimulating Research Skills in Undergraduate Computing Students: An Experience Report," in 2022 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden, 2022 pp. 1-9.

[8] doi: 10.1109/FIE56618.2022.9962694

[9] Hurtado, S., Eagan, M. K., Tran, M. C., Newman, C. B., Chang, M. J., & Velasco, P. (2011). "We do science here": Underrepresented students' interactions with faculty in different college contexts. *Journal of social issues*, 67(3), 553-579.

[10] Ong, M., Wright, C., Espinosa, L., & Orfield, G. (2011). Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics. *Harvard educational review*, 81(2), 172-209.

[11] Summers, M. F., & Hrabowski III, F. A. (2006). Preparing minority scientists and engineers. *Science*, 311(5769), 1870-1871.

[12] Vicki L. Baker, Meghan J. Pifer, Laura G. Lunsford, Jane Greer & Dijana Ihas (2015): Faculty as Mentors in Undergraduate Research, Scholarship, and Creative Work: Motivating and Inhibiting Factors, Mentoring & Tutoring: Partnership in Learning, DOI:10.1080/13611267.2015.1126164"

[13] Villa, E. Q., Kephart, K., Gates, A. Q., Thiry, H., & Hug, S. (2013). Affinity research groups in practice: Apprenticing students in research. *Journal of Engineering Education*, 102(3), 444-466.

[14] Teller, P. J., & Gates, A. Q. (2001). Using the affinity research group model to involve undergraduate students in computer science research. *Journal of Engineering Education*, 90(4), 549-555.

[15] Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory into practice*, 38(2), 67-73.

[16] Brown, A. L., & Campione, J. C. (1990). Interactive learning environments and the teaching of science and mathematics. Toward a scientific practice of science education, 111-139.

[17] Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational researcher*, 25(4), 5-11.

[18] Bruner, J. (1990). Culture and human development: A new look. *Human development*, 33(6), 344-355.

[19] Massi, L., McKinzie, C. R., Gesquiere, A. J., & Seal, S. (2014, June). The influence of student-faculty interactions on post-Graduation intentions in a research experience for undergraduates (REU) program: A case study. In 2014 ASEE Annual Conference & Exposition (pp. 24-1226).

[20] Marquez, E., & Garcia, S. (2021, July). Scaffolding Student Success: Developing a Culturally Responsive Approach to Support Underrepresented Minorities in Engineering Undergraduate Research. In 2021 ASEE Virtual Annual Conference Content Access.

[21] Minshew, L. M., Olsen, A. A., & McLaughlin, J. E. (2021). Cognitive apprenticeship in STEM graduate education: A qualitative review of the literature. *AERA Open*, 7, 23328584211052044.

[22] Kwak, D., Morreale, P., Hug, S. T., Kumar, Y., Chu, J., Huang, C. Y., & Wang, P. (2022, February). Evaluation of the Use of Growth Mindset in the CS Classroom. In Proceedings of the 53rd ACM Technical Symposium on Computer Science Education-Volume 1 (pp. 878-884).

[23] Hug, S. (2021, March). How Do Faculty Convey Growth Mindset in Computer Science Teaching? A Preliminary Qualitative Study. In Proceedings of the 52nd ACM Technical Symposium on Computer Science Education (pp. 1285-1285).