PURM
Perspectives on Undergraduate Research & Mentoring

Virtual Mentorship for Online Undergraduate Research: Analysis of Mentor and Mentee Perspectives

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Introduction

Undergraduate research is a high-impact practice with mentoring as a common institutional support to bolster research persistence (Cooper et al., 2019) and self-efficacy (Estrada et al., 2018; Sams et al., 2015). Faculty also benefit from engaging as research mentors, including benefits like assistance with research workload (Faulconer et al., 2020a; King & Imai, 2022), gaining an understanding in student skill and learning needs, development of mentoring skills, and gaining feedback from students (Faulconer et al., 2020a; King & Imai, 2022).

Undergraduate research mentorship faces barriers: personal (e.g., communication, time investment), student-centered (e.g., student motivation, skills gap), and institutional (e.g., workload, recognition, embedding current research and research careers in the curriculum; Faulconer et al., 2020a; King & Imai, 2022; Adebisi, 2022). Additionally, many higher education faculty are contingent (e.g., adjunct), so students may not have ready access to mentors with recent research experience. Cultural differences are another barrier; while underrepresented minority students value cultural diversity in mentoring relationships (Byars-Winston et al., 2020; Pfund, 2016), some mentors see it as irrelevant (Prunuske et al., 2013). These issues are likely intensified in a distributed, online research and mentorship environment.

Compounding this is the global lack of consensus regarding what constitutes a mentor versus a supervisor. Throughout published research, policies, and institutional programs, these terms are frequently conflated and used interchangeably. Additionally, distinctions in the roles may differ by contexts. For example, in Australian higher education, a research supervisor provides task-focused disciplinary oversight where a mentor fulfills a broader development-focused role by providing psychosocial support, career socialization, and support for development of professional identity. Conversely, in the United States prominent organizations like the Council on Undergraduate Research structurally combine the functions of research mentor and supervisor. The roles are distinct even when the responsibilities overlap, a concern noted over two decades ago (Bird, 2001) that does not seem to be resolved yet.

To address this ambiguity, this study establishes clear, functional definitions for both roles based on their primary objectives:

- *Research mentoring* is defined as "a collaborative learning relationship that proceeds through purposeful stages over time and has the primary goal of helping mentees acquire the essential competencies needed to progress to the next stage of their career" (Pfund, 2016). The core focus of a mentor is to provide developmental, holistic, and long-term guidance, with emphasis on psychosocial support, career socialization, and the cultivation of professional identity.

- *Research supervision* is task oriented, output-driven, and connected to the lifecycle of an active project. The core focus of a supervisor is disciplinary oversight, project management, and achieving final dissemination of research outcomes that align with disciplinary norms.

In disaggregating and disambiguating these terms, researchers still note an existing need for: 1) a clear, functional definition of mentoring, 2) a detailed context for the mentoring relationship, and 3) a detailed list of roles the mentors are playing (Pfund, 2016).

Navigating these barriers requires a structured approach to assessing the mentoring relationship. The literature identifies core mentor competencies necessary to overcome these challenges, including maintaining effective communication, aligning expectations, assessing understanding, fostering independence, addressing diversity, and promoting professional development (Fleming et al., 2013). These domains define the operational, cognitive, and cultural parameters of a successful research mentoring partnership:

- *Maintaining effective communication:* Communication is a foundational requirement to navigate potential hurdles in undergraduate research (Bennett et al., 2022) and is a critical task in National Science Foundation-funded professional development frameworks (Greenberg, 2018). While virtual mentoring offers flexibility and interaction records, the environment introduces distinct technology challenges, privacy concerns, and risks for miscommunication (Seyed Alitabar & Zadhasn, 2014).

- *Aligning expectations:* As research expectations can evolve over time, mentors and mentees must engage in frequent measures to ensure alignment of expectations (Greenberg, 2018). Effective mentors calibrate student expectations that may drift outside of scope or workload realities, intentionally establishing appropriate challenge while ensuring achievements are attainable (Walkington et al., 2020).

- *Assessing understanding:* A productive mentoring relationship requires explicit validation of a mentee's comprehension (Greenberg, 2018; Stephenson et al., 2022; Walkington et al., 2020). This assessment includes assessing mentee prior knowledge, grasp of core concepts, and procedural capabilities relative to the research tasks. The mentor can then identify intervention strategies.

- *Fostering independence:* Mentors actively cultivate mentee self-confidence to foster the independence needed to transition toward project ownership and research autonomy (Greenberg, 2018; Pfund, 2016; Walkington et al., 2020).

- *Addressing diversity:* Cultural and background diversity introduces opportunities alongside complexities (Greenberg, 2018). Effective mentors self-reflect on their biases and implement strategies for addressing them, and they also demonstrate active listening and empathy in conversations about diversity with their mentees (Hoffman et al., 2023).

- *Promoting professional development:* Mentors can promote their mentees' professional development by helping them find work-life balance (Bennett et al., 2022), building a sense of community, and providing networking opportunities (Walkington et al., 2020). Working in faculty-mentored research teams can influence career intentions (Stiles et al., 2023).

Research Questions

Mentor self-assessment and mentee assessment of mentoring is important to improving the quality of research mentoring programs and professional development of faculty. This study presents the results of a parallel assessment of an undergraduate research mentorship program where both the mentorship and the research are completed using a globally distributed online model, with clearly defined roles for research mentors and research supervisors. We seek to understand the following research questions:

1. Do mentors self-perceive strong mentoring skills in all six of the mentor competencies?
2. Do mentees perceive strong mentoring skills in all six of the mentor competencies?
3. Is there strong alignment between the mentor self-assessment and the mentee assessment of mentoring in the program?

Literature Review

Because research mentoring and supervision are routinely conflated, isolating the precise impact of mentorship remains problematic. In fact, because workload and the need for professional development are key barriers to academics' support of undergraduate research, disaggregating the roles of research mentorship and research supervision could alleviate this barrier. Research mentors could offer long-term high-level support going beyond disciplinary expertise, focusing on helping students navigate the path from research curiosity to being research engaged, with attention to skills development, self-reflection, and ownership along the way. Research supervisors, then, could offer the disciplinary expertise necessary to successfully execute a research project and would receive students who have already worked to address deficiencies in skills and knowledge and come prepared to launch a project.

In recent years, there has been marked attention on virtual research mentorship for undergraduate research, but this is an emerging area where evidence to support best practices is developing. Recent focus areas include using a mentor constellation model (multiple mentors) and cohort mentoring (Hall et al., 2021; Johnson & Knox 2022) and adaptation of the Salient Practices framework (Hall et al., 2021). Studies of undergraduate research mentoring suggest its efficacy in improving sense of belonging, growth in employability skills, personal growth, and an increased understanding of the nature of research (Faulconer et al., 2024), as well as increased knowledge of, and confidence in applying for graduate studies (Silverstein et al., 2022). Virtual undergraduate research mentoring can also increase cross-cultural collaborations and expand professional networks, fostering inclusivity and support that is important for all mentees but particularly significant for mentees from underrepresented groups (Knox et al., 2023). We were unable to locate data comparing experiences and outcomes for virtual versus in person undergraduate research mentoring.

Earlier research into the perspectives of mentors and mentees in student research have shown significant differences in how each party interprets the other's skills and abilities. In a study of students' research self-efficacy (Lev et al., 2010), mentees often underestimate their research self-efficacy compared to mentors' perceptions of their abilities. When asked about their perceptions on students' developing research skills, such as development of a literature review, analysis, and data interpretation (Feldon et al., 2015), mentors and mentees often named different strengths and

weaknesses. For a possible cause of these differences, the authors of this study hypothesized that the mentor might not have had enough interaction with the student to be able to directly assess these research skills. The difference in perspective regarding the availability of the mentor and expectations of mentoring from a faculty member was also a key point from a study of students taking part in an Undergraduate Research Experience program (Behar-Horenstein et al., 2010). However, students and faculty both agree that mentoring increased the students' technical expertise and communication. Differences in mentor and mentee perspectives can have a major effect on how mentees accept and apply feedback provided by the mentor (Korver & Tillema, 2014). Mentoring style also seemed to have an observable impact on the perception of the feedback.

Regardless of the scope of the mentor or modality of the mentoring relationship, it is important that research mentors receive formal training. A recent national survey noted that only 7% of research mentors reported significant training (Stolzenberg et al., 2019). As more students engage in exclusively online degree programs, it is important to consider how to offer support in a distributed model. There is some evidence that in-person and online mentor training are both effective (Rogers et al., 2022). Formal training can also provide the opportunity to develop faculty cultural literacy (intercultural knowledge and competence) to improve research mentoring relationships, which is not always provided in the traditional forms of scientific training research mentors have experienced and engaged in (Byars-Winston et al., 2020; Pfund, 2016).

In the last decade, metrics have been developed and validated to assess research mentoring such as the Mentor Evaluation Tool (Yukawa et al., 2020), the internationally used Mentor's Competence Instrument (Tuomikoski et al., 2018) and the Mentoring Competency Assessment (MCA) (Fleming et al., 2013). There is no single instrument that fits all mentors and mentees, but there is a need for an instrument that allows for parallel measurement as there is limited comparison of mentor-mentee perceptions of mentoring competency. One study noted mentees showed a wider range of opinions and a more negative overall sentiment of mentor competency than what mentors self-reported, particularly for skills like communication, aligning expectations, and fostering independence (Orsini et al., 2019).

To investigate perceptual gaps, the literature emphasizes core behavioral domains that define mentoring competency (Fleming et al., 2013; Pfund et al., 2016). Maintaining effective communication and aligning expectations are foundational competencies that ensure goal and process clarity. Assessing understanding and fostering independence are competencies that target cognitive growth. Addressing diversity and promoting professional development are competencies that ensure the relationship remains culturally responsive and aligns with long-term career trajectories.

Methods

Context: Defining Roles

At the study's institution, the roles and responsibilities of research mentors and research supervisors were distinctly articulated. A faculty member may serve as both mentor and supervisor to an undergraduate researcher, but the roles are unique.

The relationship between research mentors and students is long-term, with mentors offering support from when students first express an interest in research through to research culmination. Mentor support can relate to psychosocial dimensions (e.g., emotional and personal support), role modeling (e.g., offering intellectual support and demonstrating attitudes and behaviors for success in a given context), or a career function (e.g., professional socialization, professional development, sponsorship, or coaching; Pfund, 2016). Research mentors routinely meet with mentees online to discuss expectations and goals, navigate barriers and hurdles, develop key research and

transferable skills, and explore a research-focused career path. A research mentor has strong research experience but is not necessarily a subject matter expert in the students' area of research. Mentor-mentee coordination, including recruitment, assignment, and reporting details occurs among an institutional mentoring organization, the research team, and the individual faculty research mentors with the mentors responsible for entering critical details into a shared document.

The relationship between research supervisors and students is typically short-term, limited to the duration of active research. The research could be an existing project or topic originated with the research supervisor or proposed and pursued solely by the student, within the oversight of the faculty member. The research supervisor supports completion of a specific research project, including the dissemination of the research through structuring and supporting project management, methodology, data analysis, and communication aligned with disciplinary norms. Ideally, the research supervisor is a subject matter expert in the students' area of research.

Context: Mentoring Program

Students completed an application to be matched with a mentor by the program coordinators. Mentors typically support 4–8 mentees at a time, with workload negotiated at the department level. Research mentors complete online training that covers basic mentoring skills and includes the production of a research mentoring philosophy written for a mentee audience. Online versus in person mentor training has shown consistent outcomes for research mentors (Rogers et al., 2022).

Materials

The Mentoring Competency Assessment (MCA) was selected as the most appropriate for this study for three reasons. First, it uniquely addresses the need for parallel measures by using instrument items phrased for mentors and mentees for evaluating alignment in our parallel investigation. Second, the instrument has been widely used (Harker et al., 2019; Orsini et al., 2019; Wiskur et al., 2020) and extensively validated for assessing effectiveness of the mentoring relationship from both mentor and mentee perspectives (Fleming et al., 2013). Furthermore, it has been revalidated in multiple contexts (Hyun et al., 2022). Third, the MCA focuses on behavioral competencies that are independent of modality, making it well suited to capture the core dynamics of a virtual mentoring relationship.

As the instrument was unchanged in this study, we did not revalidate the instrument. The condensed MCA instrument (Hyun et al., 2022) contains 21 items using a 7-point Likert-type scale with 1 = not skilled at all and 7 = extremely skilled. The scale also included an "N/A" option when the respondent felt that a skill could not be evaluated. The instrument contains six subscales: maintaining effective communication (4 items), aligning expectations (4 items), assessing understanding (3 items), fostering independence (3 items), addressing diversity (3 items), and promoting professional development (4 items). Mentors were asked to provide scores as a self-reflection on their own mentoring skills while mentees were asked to provide scores for their research mentor's skills. The survey also included four demographic and background questions covering age range, gender, ethnicity, and educational program.

Participants and Procedures

This study was deemed exempt through the Institutional Review Board (#23-103) at the institution where the research mentoring program was conducted. Participants were recruited through email communication and informed consent was collected. Online questionnaires were distributed through Qualtrics. From a population of 6 mentors ($N_{Mentors}$) and 23 mentees ($N_{Mentees}$), the response rate was 33% ($n_{Mentors}$ =2) and 26% ($n_{Mentees}$ = 6), respectively. While these response rates align with similar studies using this instrument (Orsini et al., 2019; Wisker et al., 2022), the resulting sample sizes mean the findings must be treated as localized, exploratory metrics, not generalizable parameters.

Table 1 depicts the characteristics of the mentors and mentees that participated in the survey. To protect confidentiality, mentors assigned to specific mentees are designated in Mentor Groups A (3 mentees) and B (3 mentees). Mentee responses returned where the mentor did not participate were not included in any of the analyses.

Table 1. *Mentor and Mentee Characteristics, Counts, and Respective Population Percentage*

Demographic Variable	**Mentor** Count, (%)	**Mentee** Count, (%)
Gender		
Female	2 (100%)	4 (66.67%)
Male	0 (0%)	2 (33.33%)
Non-binary	0 (0%)	0 (0%)
Prefer not to say	0 (0%)	0 (0%)
Age range		
18-24	0 (0%)	2 (33.33%)
25-34	0 (0%)	3 (50.0%)
35-44	1 (50.0%)	0 (0%)
45-54	1 (50.0%)	1 (16.67%)
Ethnicity		
Asian	0 (0%)	1 (16.67%)
Black or African American	0 (0%)	0 (0%)
Indian	0 (0%)	1 (16.67%)
White	2 (100%)	2 (33.33%)
Prefer not to say	0 (0%)	1 (16.67%)
Other	0 (0%)	1 (16.67%)

Data Analysis

To evaluate overall competencies rather than individual survey items, responses were grouped and analyzed by competency subscale. Cronbach's α was calculated by competency to ensure the collapse of items to associated competency factor was appropriate. Four of six competency factors reported acceptable Cronbach's α of above 0.7. The other two reported a Cronbach's α of 0, suggesting the survey participants presented nearly identical scores for the competency factor. Therefore, while the first four competencies were analyzed as aggregated scales, the items within the remaining two competencies had to be treated as individual items due to internal consistency.

Mean scores were compared using *t*-statistics. A *t*-test was deemed appropriate because the population standard deviation is unknown, making the *t*-distribution the correct framework for evaluating the sample means. All statistical calculations were performed using Microsoft Excel. To evaluate the proficiency of mentoring skills, a mean score of 6.0 on the 7-point Likert scale (where 1 = not skilled at all and 7 = extremely skilled) was established as the benchmark representing "strong" mentoring ($\mu \geq 6.0$).

One-tailed, one-sample t-tests were conducted for the first two research questions to determine if the observed sample average ratings significantly exceeded this "strong" mentoring skills threshold. The third research question used a two-tail paired-samples *t*-test ($\mu_1 \neq \mu_2$) to evaluate the alignment and detect any differences between mentor self-assessments and mentee evaluations.

Results

To compare mentees' and mentors' perceptions of mentor competencies, we consider the null hypothesis to be that both populations' average ratings are equal ($\mu_1 = \mu_2$) and the alternative hypothesis as the populations' average ratings are not equal ($\mu_1 \neq \mu_2$). Thus, to have evidence for

strong alignment between the mentor self-assessment and the mentee assessment of mentoring, we want to fail to reject the null hypothesis that the populations' average ratings are equal.

Mentor Self-Assessed Competency Thresholds (RQ 1)

The first research question was aimed at understanding how mentors perceived their own mentoring competencies in six areas. Given the small sample size for mentors, a two-tailed t-test was done to determine if the participating mentors shared similar self-perceptions. No differences between mentors were found (Appendix 1), so data from both mentors were aggregated (Table 2).

To operationalize the concept of "strong" mentoring skills, a mean score of 6 or higher on the 7-point Likert scale was designated as the threshold. The hypothesis test for each competency from the aggregate mentors' self-ratings is provided in Table 2. Results suggest that mentors rated themselves as strong in one of six competencies (Aligning Expectations) when considering a significance level of 0.10.

Table 2. *One-tail Hypothesis Test Results on Mentor Self-Ratings by Category with Null Hypothesis $\mu < 6$ and Alternative Hypothesis $\mu > 6$*

	Observations	Mentor Self-Rating (Mean±SD)	*t* value	df	*p*
Maintaining Effective Communication	8	5.75 ± 0.71	-1.00	1	7.5E-1
Aligning Expectations	8	6.63 ± 0.52	3.42	1	9.1E-2
Assessing Understanding	6	6.33 ± 0.52	1.58	1	1.8E-1
Fostering Independence	6	6.50 ± 0.84	1.46	1	1.9E-1
Addressing Diversity	6	6.00 ± 0.63	0.00	1	5.0E-1
Promoting Professional Development	8	6.13 ± 0.83	0.42	1	3.7E-1

Note: Observations represent the total item-level responses calculated across all survey items within the subscale across respondents. The number of respondents in each row was 2.

Mentee Perceptions of Core Mentoring Competencies (RQ 2)

The second research question was aimed at understanding how mentees perceived their mentor's competencies in six areas. Results suggest there is no evidence that the average ratings by competency are different by mentee group (Appendix 2) and thus it is reasonable to consider all mentee ratings together. The hypothesis test for each competency from the population of all mentee's ratings of mentors is provided in Table 3. Results suggest that mentees deem mentors strong (rating 6+) in all six competencies at significance levels 0.05 and 0.1.

Table 3. *Results of One-Tail Hypothesis Test Comparing Mentees' Average Ratings of Mentors by Category with Null Hypothesis $\mu < 6$ and Alternative Hypothesis $\mu > 6$*

	Observations	Mentee Rating of Mentors (Mean±SD)	*t* value	df	*p*
Maintaining Effective Communication	24	6.67 ± 0.70	4.65	5	2.8E-3
Aligning Expectations	24	6.58 ± 0.88	3.25	5	1.1E-2
Assessing Understanding	18	6.72 ± 0.46	6.65	5	5.8E-4
Fostering Independence	18	6.55 ± 0.70	3.34	5	1.0E-2
Addressing Diversity	15	7.00 ± 0.00	NA	5	0.0E1
Promoting Professional Development	18	6.78 ± 0.73	4.51	5	3.2E-3

Note: Observations represent the total item-level responses calculated across all survey items within the subscale across respondents.

Alignment between Mentor and Mentee Perceptions (RQ 3)

The third research question evaluated the alignment between academics' self-assessment and mentee assessment of mentoring for six competencies. A hypothesis test for each competency comparing mentor self-rating and student evaluations is provided in Table 4. Results suggest group A did not have evidence for misaligned perception for all six competencies while group B had evidence for misaligned perception for four of the six competencies (Maintaining Effective Communication, Assessing Understanding, Fostering Independence, and Promoting Professional Development). On all competencies with misalignments, mentees rated their mentors higher than the mentor's self-rating, with statistically significant differences. In other words, mentors were either aligned with student perception of their competency or were perceived as more competent than they gave themselves credit for. The alignment between mentor and mentee average rating assessments by group is visualized in Figure 1.

Table 4. *Results from t-test on Using Mentor Mean as Hypothetical Mean Compared Against Mentee Ratings*

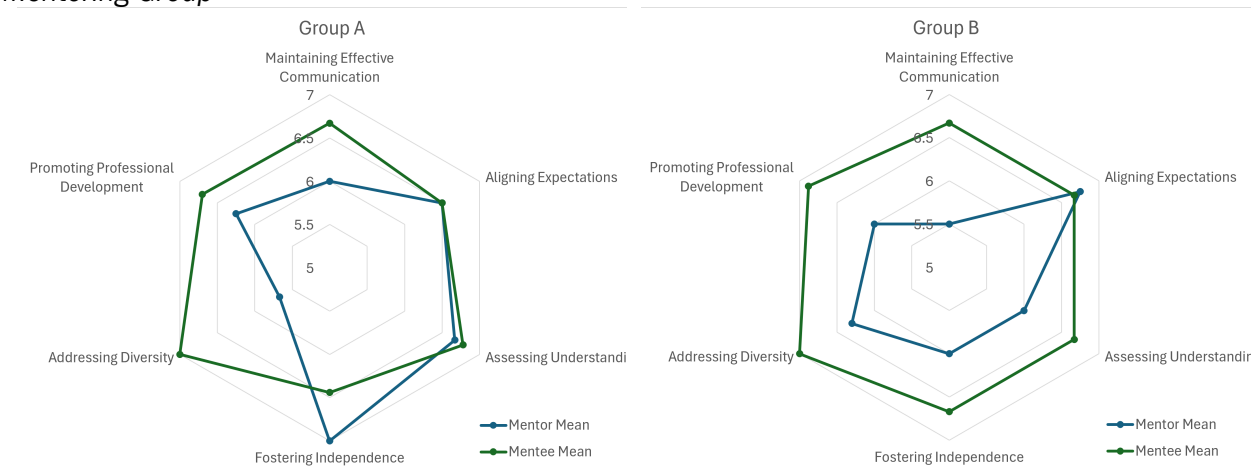
	Mentor Mean	Observations	Mentee Rating of Mentors (Mean±SD)	*t* value	df	*p*
Group A						
Maintaining Effective Communication	6.00	12	6.67 ± 0.89	2.60	2	1.2E-1
Aligning Expectations	6.50	12	6.50 ± 1.17	0.00	2	1.0E1
Assessing Understanding	6.67	9	6.78 ± 0.44	0.73	2	5.4E-1
Fostering Independence	7.00	9	6.44 ± 0.88	-1.89	2	2.0E-1
Addressing Diversity	5.67	9	7.00 ± 0.00	NA	2	0.0E1
Promoting Professional Development	6.25	10	6.70 ± 0.95	1.50	2	2.7E-1
Group B						
Maintaining Effective Communication	5.50	12	6.67 ± 0.49	8.21	2	1.5E-2
Aligning Expectations	6.75	12	6.67 ± 0.49	-0.59	2	6.2E-1
Assessing Understanding	6.00	9	6.67 ± 0.50	4.00	2	5.7E-2
Fostering Independence	6.00	9	6.67 ± 0.50	4.00	2	5.7E-2
Addressing Diversity	6.33	6	7.00 ± 0.00	NA	2	0.0E1
Promoting Professional Development	6.00	8	6.88 ± 0.35	7.00	2	2.0E-2

Discussion

Examining the research findings on mentor competencies, as perceived by both mentors and mentees, assists in highlighting key areas of alignment and divergence. The first research question featured examination of how mentors perceived their own mentoring competencies in six areas. There was statistically significant evidence for mentors rating themselves as strong in one of six competencies (Aligning Expectations) when considering a significance level of 0.10. Five of the six competencies had an average rating at or above 6, while the last competency (Maintaining Effective Communication) had an average rating of 5.75. This suggests that while there was not statistically significant evidence that the mentors rated themselves as strong in these three areas, the average ratings at or near 6 suggest the mentors perceive themselves as strong in all six competencies.

While mentors' self-assessments revealed areas where they felt their baseline skills did not exceed the "strong" threshold set in this analysis (Table 2), the aggregate evaluation from their mentees painted a different picture. Mentees perceived their mentors as exceptionally strong across all six core mentoring competencies (Table 3). When evaluating alignment between individual mentors and their corresponding mentee groups, a reader might expect to see a localised mismatch concentrated within the three subscales where mentors under-rated themselves (Maintaining Effective Communication, Addressing Diversity, and Promoting Professional Development). However, the data reveals a more nuanced and individualized variance. As detailed in Table 4, there was statistically significant evidence that the alignment between mentor and mentee competency perspectives was different for each mentor-mentee cohort, even though there was no statistically significant evidence for each mentor self-assessing differently (Appendix Table 1). Figure 1 is a storytelling device to illustrate the shape of these discrepancies. Rather than illustrating random disagreement, the radar graph emphasizes that student perceptions envelop both mentors' self-perceptions; both were viewed as highly capable by their students. However, Mentor B's self-assessment was misaligned with their mentees perceptions across five of the six domains, illustrating a pattern of self-deprecation across all mentoring behavior fields. The key understanding drawn from this illustration is that mentees experienced mentorship quality that exceeds the credit mentors gave themselves.

Figure 1. *Radar Map of Mentor-Mentee Agreement on Mentoring Competency Domains by Mentoring Group*



It is important to note that the *perception* of competency, and not mentor competency, was measured. That mentors *perceived* their competencies as lower than their mentees' perceptions of their competencies is not inherently bad. The mentors had multiple mentees and could compare their experiences. Thus, it is likely that mentors' perceptions of competency are more accurate than their mentees' perceptions. High mentee perception of their mentor's competencies does suggest mentees were satisfied with their mentoring. We continue this discussion of mentor-mentee perception by competency.

Mentor Competency Subscales

The analysis of mentor competency subscales provides a foundation for a more detailed exploration of individual competencies, including maintaining effective communication, aligning expectations, assessing understanding, fostering independence, addressing diversity, and promoting professional development, each of which are examined in the following sections.

Maintaining Effective Communication

In this study, effective communication appeared as a strength of virtual research mentors, as

reported by both mentors and mentees (Tables 2 and 3). However, an alignment gap emerged where both mentee cohorts rated their mentors' communication skills substantially higher than the mentors rated themselves (Table 4). This suggests that while faculty perceive room for personal growth, the distributed online framework successfully met or exceeded student expectations. This pattern of mentor self-deprecation alongside strong student satisfaction mirrors findings in traditional face-to-face undergraduate mentoring programs (Harker et al., 2019; Orsini & Stedman, 2022). Effective communication in virtual research mentoring can be supported through scheduling frequent video-synchronous meetings, requesting the student bring a specific item (e.g., research idea, outline, draft, etc.) to the meeting, and documentation of communications and meetings (Pfund et al., 2021; Speer et al., 2021).

Aligning Expectations

In this study, aligning expectations appeared as a strength of the virtual research mentors, as reported by both mentors and mentees (Appendix Table 2 and Table 4). For this competency, there was close alignment between mentor self-assessment and the mentees' assessment (Table 4). Faculty self-identified a growth opportunity in aligning expectations in recent studies with an in-person mentoring environment (Harker et al., 2019; Orsini & Stedman, 2022), but this finding was not seen in our virtual population. Additionally, other studies showed a discrepancy between mentee evaluation and mentor self-evaluation of this skill (Harker et al., 2019), while our results showed alignment between perceptions for this skill.

Assessing Understanding

In this study, assessing understanding was identified as a strength of the virtual research mentors (Appendix Table 2 and Table 4). In our study, there was less room for mentor growth in this area as compared to results published in other works (Harker et al., 2019; Orsini & Stedman, 2022). However, there was close alignment between mentor and mentee perceptions in one group and misaligned perceptions in the other group (Table 4). Previous work shows close alignment between mentors and mentees for this skill in an in-person mentoring environment (Harker et al., 2019).

Overestimating a mentee's disciplinary knowledge may lead to feeling overwhelmed by navigating what is known in the discipline, while underestimating a mentee's disciplinary knowledge may lead to a perception of micromanagement – both of which can negatively impact a mentee's satisfaction with their overall mentor experience. Given that the mentoring program studied did not provide perfect disciplinary matches between mentors and mentees, it may be necessary to provide additional professional development on how to assess understanding outside of one's discipline.

Fostering Independence

In this study, fostering independence was identified as a strength of virtual research mentors (Appendix Table 2 and Table 4). However, there was some misalignment between mentees and mentors, with mentees rating the mentor competency of fostering independence higher than how one of the mentors rated themselves (Table 4). Previous works evaluating in-person mentoring showed a misalignment between mentors and mentees for this skill (Harker et al., 2019). In our study, there was less room for mentor growth in this area as compared to results published in another study (Harker et al., 2019; Orsini & Stedman, 2022).

Expert mentors must negotiate the creation of opportunities for students to experience freedom and creativity in their research projects with the need to adequately provide oversight on the topic, quality, and outcomes (Walkington et al., 2020). It takes careful communication and alignment of expectations for the mentor and mentee to define the knowledge and skills of an independent mentee (Greenberg, 2018). Fostering independence is a known challenge for faculty as they may be inclined to mold students into their own image (mentor-protégé model) and may take a heavy-

handed approach in that process (Johnson et al., 2015). Students engaged in research also tend to be highly supervised, so careful attention to building confidence and independence is critical to building independent researchers (Bennett et al., 2022). Successful completion of mentored undergraduate research leading to gains in self-confidence and independence (Ghebreyessus et al., 2021).

Addressing Diversity

In this study, addressing diversity was identified as a strength of the virtual research mentors by the mentees (Table 4), but by only one of the mentors (Table 2). This led to uneven low alignment between mentor and mentee assessment of this competency (Tables 4), which was not seen in other works (Harker et al., 2019). In our study, there was room for mentor growth in this area, which was also seen in recent works (Harker et al., 2019; Orsini & Stedman, 2022). Addressing diversity has been one of the more challenging topics to address in research mentoring (Greenberg, 2018). Professional development for research mentors using structured, culturally focused content to facilitate mentor cultural diversity awareness can improve mentor's perceived mentoring skills and their confidence in enacting culturally responsive mentoring behaviors (Byars-Winston et al., 2023).

Promoting Professional Development

In this study, promoting professional development was identified as a strength of virtual research mentors by mentees and mentors (Tables 3 and 5), though some misalignment was observed (Table 4). This echoes findings of misalignment in other studies where there was room for growth noted for this skill in both online and in-person mentoring (Harker et al., 2019; Orsini & Stedman, 2022). To improve mentee professional development, mentors may benefit from a stronger understanding of their mentees' network as mentees may have a 'mentoring mosaic' formed by multiple people that interact with them around the shared research interest. Secondary mentors can help fill gaps in support not provided by the primary faculty mentor.

Implications for Practice

The overall high competency ratings from both mentors and mentees suggest that virtual mentorship can indeed successfully overcome common institutional and individual challenges for student researchers and their mentors. The areas where mentor and mentee perspectives diverged, as well as areas with lower ratings, offer actionable data for crafting targeted professional development. Using mentoring competency evaluation to drive professional development has been suggested for in-person mentoring (Mickel et al., 2018). Online professional development can improve mentor skills as well as mentor confidence in their ability to mentor effectively (Behar-Horenstein et al., 2019). Professional development on research mentoring has shown significant gains in the mentoring competencies of maintaining effective communication, aligning expectations, and addressing diversity, equity, and inclusion (Young & Stormes, 2020). Furthermore, prior professional development is a predictor of positive self-evaluations of mentoring competence (Orsini & Stedman, 2022).

High-quality mentoring has many positive effects on undergraduate researchers, including the sense of belonging (Monarrez et al., 2020), which is important in fully online research experiences where a sense of community may be lacking (Faulconer et al., 2020b).

Limitations

Several limitations stem from small sample size. A larger sample size can mitigate limitations of the hypothesis test on a skewed distribution resulting from the capped Likert scale. Using a *t*-statistic rather than *z*-statistic mitigates this limitation. However, the sample size of n = 2 for the participating mentors makes it impossible to draw sweeping conclusions or apply these findings to all virtual mentoring contexts. Furthermore, performing inferential tests on small sample sizes carries inherent

constraints. This data should be interpreted strictly as a pilot evaluation of this specific program's framework. Means were provided alongside inferential statistics to support evaluation of these potential trends.

Sample size prevented evaluation of mentor and mentee heterogeneity on perspectives related to mentoring competencies. This is an important aspect to explore further as there is uncertain data from other studies regarding research mentoring relationship heterogeneity (Orsini et al., 2019). Other potential variables like mentoring frequency may also influence positive self-evaluation of mentoring (Orsini & Stedman, 2022).

Furthermore, because multiple mentee evaluations were nested within a mentor cohort, the data does inherently violate independent observation. While a multilevel analysis would be most appropriate for this nested structure, the pilot sample size precluded this approach. Standard t-tests were used for this exploratory baseline, but future expanded studies will seek a larger institutional sample to avoid this limitation.

Data was collected from a single point in time from one institution, limiting generalizability, though this is inherently limited by the institutional variation in undergraduate research mentorship support for fully online students.

Reliance on self-reported data from the MCA instrument introduces the potential for social desirability bias, selection bias, and nonresponse error. We attempted to mitigate this limitation through recruitment measures.

Recommendations for Future Research

While these preliminary findings should be interpreted with caution, they do offer insights into the potential effectiveness of virtual research mentoring. Future research should conduct larger, longitudinal studies to enhance generalizability. It is also critical to investigate the discrepancies between mentor and mentee perspectives, exploring how these might influence student researcher outcomes. Future research might examine the causes of such misalignments and investigate strategies to improve mutual understanding and expectation management. Finally, research should evaluate mentor development programs to assess how targeted training might improve virtual mentoring competencies.

Conclusion

This study addresses the need for research on virtual undergraduate research mentoring and, more broadly, responds to Pfund's (2016) call for advancing research on undergraduate research mentoring by defining mentoring functions, providing context for mentoring relationships, and identifying key mentor roles in fostering effective mentorship. By utilizing a validated metric to compare mentor and mentee perspectives on mentor competencies, the research demonstrates methodological rigor, providing new insights into virtual mentoring within a wholly online learning environment. While many institutions transitioned to virtual mentorship during the COVID-19 pandemic, a larger body of evidence is needed in this space.

Both mentors and mentees generally agreed that mentors exhibited strong competencies in areas such as communication management, expectation alignment, and fostering independence. Interestingly, mentees rated their mentors' competencies higher than mentors rated themselves.

While the sample size limits generalizability, these findings provide initial evidence of effective virtual mentoring. The self-identified areas for growth and the gaps between mentor and mentee perceptions suggest promising avenues for further exploration, particularly in developing and

evaluating mentor training programs aimed at improving skills and closing the perception gap. This study sets the foundation for future research on optimizing virtual mentoring practices and mentor training.

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Appendix 1

To justify combining the mentor data and thus maximize the statistical power, a two-tailed *t*-test was conducted to evaluate baseline differences between the mentors. Due to the small sample size inherent to this specialized undergraduate research environment, two significant thresholds were established to evaluate the strength of the evidence, where $\alpha = 0.05$ was the primary threshold for statistical significance and $\alpha = 0.10$ was monitored as a secondary threshold indicating a marginal or emerging trend. As shown in Appendix Table 1, no statistically significant differences were found across the six subscales ($p > 0.05$). Thus it is reasonable to aggregate data, considering all mentor ratings together.

Appendix Table 1

Two-tail Hypothesis Test Comparing Average Score by Competency between the Mentors with Null Hypothesis $\mu_1 = \mu_2$ and Alternative Hypothesis $\mu_1 \neq \mu_2$

	Mentor A Mean	Mentor B Mean	p-value
Maintaining Effective Communication	6.00	5.50	3.6E-1
Aligning Expectations	6.50	6.75	5.4E-1
Assessing Understanding	6.67	6.00	1.2E-1
Fostering Independence	7.00	6.00	1.6E-1
Addressing Diversity	5.67	6.33	2.3E-1
Promoting Professional Development	6.25	6.00	7.0E-1

Appendix 2

A hypothesis test for each competency comparing mentee ratings for mentor A and mentor B is provided in Appendix Table 2. Results suggest there is no evidence that the average ratings by competency are different by mentee group and thus it is reasonable to consider all mentee ratings together.

Appendix Table 2

Two-Tail Hypothesis Test Comparing Average Score by Competency between the Two Mentee Groups with Null Hypothesis $\mu_1 = \mu_2$ and Alternative Hypothesis $\mu_1 \neq \mu_2$

	Mentee A Rating Mean	Mentee B Rating Mean	p-value
Maintaining Effective Communication	6.67	6.67	1.0E1
Aligning Expectations	6.50	6.67	6.5E-1
Assessing Understanding	6.78	6.67	6.2E-1
Fostering Independence	6.44	6.67	5.2E-1
Addressing Diversity	7.00	7.00	1.0E1
Promoting Professional Development	6.70	6.88	6.3E-1