Evaluating Exploratory Reading Groups for Supporting Undergraduate Research Pipelines in Computing

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Abstract

This paper reports on a summative analysis of Exploratory Reading Groups (ERGs), a low time-commitment, relational, student-led reading group program designed to provide students from any background and year with a broad exploration of computing research. Since prior work, the program was institutionalized as a 1-credit course with a greater emphasis on strengthening pipelines into research labs. In analyzing 3 quarters of data from 136 participants, we found diverse indicators of impact. Surprisingly, despite the lightweight nature of the program (~2 hours/week), we observed a statistically significant increase in satisfaction with their intellectual development at the university; confidence in reading, presenting, and communicating about their field; sense of belonging for women and minoritized ethnic groups; alignment with faculty goals in joining research labs (greater desire to make a research contribution and publish, decreased desire to join for the purpose of exploration); and engagement in the 'reconsideration' dimension of career identity formation. Over 70% of the participants continued on into group research projects for undergraduate students. The effectiveness of this scalable, lightweight initiative shows the promise of ERGs as a tool to support students in computing when connected to group research projects and points to future research directions on designing other lightweight, relational, scalable learning experiences.

CCS Concepts

• **Social and professional topics → Computational science and engineering education**.

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1 Introduction

Students studying computing often do not get to engage with the more creative and societally relevant aspects of the field until they get past foundational technical courses and into upper-division elective courses. Undergraduate research experiences (UREs) are one way students can engage with computing in this way, but they also mostly center on later-stage students who have built up prior experience. This is unfortunate, especially given research showing that providing purpose for learning can enhance motivation and retention for underrepresented students in computing [25] and that UREs can increase the likelihood of pursuing graduate study, improve retention for STEM, clarify career goals, and enhance various hard and soft skills [5, 15, 20, 21, 36, 48, 52, 53], with benefits sometimes being stronger for underrepresented minority (URM) students [30, 51].

To address this, prior work introduced Exploratory Reading Groups (ERGs), a low time-commitment, relational, student-led reading group program designed to provide students from any background and year with a broad exploration of computing research. Besides the exploratory value they provide students, the program was also found to support entry into UREs [44, 55].

This paper reports on a summative analysis of ERGs over three quarters after it was institutionalized as a 1-credit course and refocused around strengthening pipelines into research labs, with student participants guaranteed the opportunity to join group research projects in subsequent quarters if they wanted to. Our analysis of

136 participants showed that the various experiences observed anecdotally in formative work were experienced by many students (e.g. being exposed to new ideas, developing relationships, receiving academic and emotional support, etc.). We also found statistically significant impacts of ERGs. Between the intro and exit surveys of a given quarter, we found increased satisfaction with intellectual development at the university and a change in motivations for participating in research labs to better align with faculty goals (an increase in wanting to join research labs to make a research contribution and publish it and a decrease in wanting to join for the purpose of exploration, presumably due to their exploratory needs having been met by the reading groups). Students also experienced an increased confidence in research-related activities (reading papers, presenting ideas, engaging in discussions, and sharing the impact of their field), and female and non-white/asian students experienced an increased sense of belonging (though interestingly, male and white/asian students experienced an increase in feelings of being an outsider and of making things up in discussions about their field). We also saw increased 'reconsideration' in career identity development, which qualitative data indicate mostly center around having a new appreciation for research. The fact that these results were obtained from such a low time-commitment program (~2 hours/week) is promising, suggesting the value of further studies around exploratory reading groups and in designing other lightweight, relational, and scalable learning experiences, especially when those experiences can be tied to opportunities for deeper engagement.

2 Related Work

2.1 Exploratory reading groups and student success in computing

Exploratory Reading Groups are situated within the literature on supporting student success in computing. Margolis et al. highlight the necessity of creating inclusive learning environments that welcome students from all backgrounds into computing, addressing systemic barriers that have historically limited diversity in the field [38]. The development of resilient and engaged computing researchers and professionals goes beyond technical knowledge; it encompasses challenges like fostering a supportive environment [37], ensuring equity and inclusion [13], and addressing the unique and personal needs and motivations of students from diverse backgrounds. For example, research shows that creating more purpose for learning and communicating the societal impact of computing helps to increase motivation and retention for underrepresented populations in CS [25, 30].

There have been many diverse approaches to increasing exploration, motivation, and purpose for learning in CS education. One such approach is enhancing courses with peer-based interactions, where students engage in mutual learning through collaborative discussions and shared problem-solving [8, 56]. Another method involves project-based learning, an approach where students apply theoretical concepts in practical, real-world scenarios through hands-on projects [23, 47]. Additionally, informal learning opportunities like hackathons offer creative coding and collaborative innovation under time constraints [42].

Identity formation plays an important role in these approaches. Großer-Bölting et al. provide a systematic literature review on identity in computing education research (CER), highlighting its importance to student success in computing. They cite that a strong subject identity within one's field greatly minimizes the risk of dropout and maximizes retention [58, 62], where "retention and diversity can be seen as 'chronic problems' of CER" [11, 24, 27, 28]. This identity formation is intertwined with students' experiences in peer-based interactions, project-based learning, and informal learning opportunities, as such environments can allow students to see themselves as members of the computing community and thus feel more connected with their field.

Exploratory Reading Groups (ERGs) add to these approaches for advancing inclusive and effective learning experiences in computing education. They also leverage peer-based interaction, but center engagement on reading and discussions, an approach that has been successfully used in an undergraduate setting in the humanities, social sciences, and physical sciences, where they have been shown to promote autonomous learning, heighten critical insight, and increase student communication and confidence [19, 22, 29, 33, 50].

2.2 Undergraduate research experiences: benefits and barriers

ERGs are most closely related to undergraduate research experiences (UREs), where undergraduates explore and build confidence in computing through research traditionally involving full-time summer-long commitments like in the CREU and DREU programs [12]. Researchers have shown many benefits to UREs. A paper highlighting case studies from five different universities showed that structured undergraduate research programs can increase motivation for attending graduate school, increase social support amongst peers, and expand students' "social networks through linkages to faculty mentors, peer support groups, and professional associations" [26]. Another study showed that UREs can increase the likelihood of students intending to attend graduate school from about 14% to 17% [20]. Moreover, UREs provide students with the opportunity to engage in scientific discourse with faculty and peers; it has been shown that students with strong and positive faculty connections are more likely to intend on pursuing graduate education [5, 20]. When evaluating undergraduate research outcomes in one article, it was found that 88% of participants stated their grasp of how to conduct a research project grew, 83% said their confidence in their research-related skills expanded, and 73% said their understanding of what graduate school is like increased [52]. Undergraduate research has been shown to help students understand how the research process works, develop the ability to analyze data, become better problem solvers, design experiments, understand concepts in their fields, and gain confidence, among other benefits [36, 48]. Additionally, an assessment of undergraduate research programs showed that participation in UREs for more than a semester is correlated with an increased GPA [21]. UREs can also be beneficial for professional development. Students participating in UNC Charlotte's research experience for undergraduates (REU) program stated that one of the most valueable elements of the program was "experiencing research as a way to achieve academic gains, and make career choices" [18].

However, many barriers to UREs exist, making such experiences selective and often limited to small numbers of (typically experienced, third-year or fourth-year) students. One significant barrier to UREs is the extensive time commitment required by faculty [5, 14, 16, 32, 40], compounded by the perception that undergraduates are unprepared for research [10]. Thus, undergraduates looking for research experiences often struggle to find faculty willing to include them in their labs [15]. Studies have shown that the main barriers lie in a lack of faculty incentive, time, resources, funding, a perceived lack of student preparedness, and a general lack of institutional support. [41, 49, 54]. For students, a lack of financial support as well as a lack of opportunities were cited as barriers [43]. Many barriers stem from misalignments between the educational system and the research world, faculty and student goals, and faculty and student expectations that result in faculty needing to spend significant amounts of time finding the right fit for students and developing team and organizational structures to support them [55]. It is clear that addressing the barriers to mentoring undergraduate research is essential to boost involvement. A case study at Northern Arizona University showed an increase of faculty involved in leading undergraduate research from 60% to 94% after 5 barriers were addressed: lack of student awareness, unequal student access, poor curricular timing, lack of publicity, and uneven access and incentives for faculty [61].

2.3 Expanding access to undergraduate research experiences

To overcome these barriers, researchers have developed approaches like course-based undergraduate research experiences (CUREs) open to large student cohorts [15, 57]. Programs like Data Analytics Research (DAR) give students the ability to engage with research solving real-world problems in a project-based setting as part of a low-barrier pipeline into the field of data analytics [7]. Another study highlighted the Early Research Scholars Program (ERSP), a computer science research program employing a dual-mentoring approach to guide students with minimal faculty burden [2, 6]. ERSP's blend of technical and project mentorship, community building, and support for underrepresented groups enriches the undergraduate research experience, and has demonstrated significant impacts in creating an inclusive and supportive research community, particularly for women and racially minoritized students [3, 4]. Finally, the CREATE (Consider, Read, Elucidate the hypotheses, Analyze and interpret the data, and Think of the next Experiment) program, developed by Hoskins and Stevens, engages students with a series of journal articles to foster deep comprehension and critical analysis of scientific literature [31]. This program has shown success in not only demystifying research but also in making it more relatable and accessible to students, encouraging a wider interest in research careers.

Researchers have also explored the development of sociotechnical systems to scale opportunities for research. For example, the Crowd Research project enabled over 1,500 participants from 62 countries to engage in open-ended research through a crowdsourcing model [60] and introduced a novel credit system for recognizing contributions. Agile Research Studios (ARS) explored computational ecosystems that blend agile methodologies, supportive social structures, and digital tools to foster large student research communities [64].

Like these programs, ERGs are designed to be accessible to students from any background and as early as their first year, to intentionally facilitate peer relationships, and to scale to large cohorts of students. The main difference is that due to the reading group format, they only provide a lightweight research experience: no research is performed, but there is exposure to research areas, scientific knowledge production, and the creation of communities of shared interest. The benefit of ERGs is that they provide an extremely low time-commitment (~2 hours/week) program that students can more easily add to a busy workload, but that naturally leads to the main question we seek to answer in this paper: *"To what extent can a lightweight research experience like Exploratory Reading Groups be able to benefit participating students?"*

3 Research Setting and Methods

3.1 Exploratory Reading Groups

ERGs are designed for exploration, relationships, and scalability. First, unlike graduate student reading groups that emphasize depth, ERGs emphasize breadth and developing purpose for learning [63], with topics phrased to connect computing to relatable societal themes and students exposed to multiple papers in each one-hour session to help them find ideas that connect or capture their imagination. Second, ERGs carve out time for relationship-building, with every ~1 hour meeting starting with a 15-minute 'get-to-know-you' activity to help students to know each other as the quarter progresses. Third, the program is sustainable and makes it easy for students and faculty to join. Students find it easy to join because of the very low time commitment, and faculty do not need to make long-term time commitments since reading groups are student-run (with the support of a launch session, a how-to-guide, and other materials).

In the original formative study, ERGs were run as a co-curricular program, with qualitative findings describing the diverse ways in which students experienced successful exploration and relational support. However, it did not contain quantitative measures evaluating how common those experiences were across the entire cohort and also did not collect data measuring the impact of participation in ERGs.

This paper seeks to fill this gap by providing a more in-depth evaluation of ERG experiences and outcomes. We evaluate an implementation of ERGs at a large public university within a 1-credit course, organized similarly to the co-curricular program [44].

Each quarter contains two five-week long phases during which students are assigned to one reading group of ~9 students based on their submitted preferences. Students have historically been placed in at least one of their top three preferred groups, with a majority being placed in their top two. The first week of each phase is a launch week for the course instructor to provide guidance, open the floor to questions from the class, and support groups in logistics. The launch week in phase 1 centers on giving an overview of the motivation for the class and the general structure for the quarter, and sharing tips for summarizing and facilitating discussion on a research paper. The launch week in phase 2 centers on how to apply to and get involved in research in future quarters, especially in the research labs of faculty sponsoring the reading group themes, some of which run group research projects taking larger numbers of students. Students are given the remainder of the launch sessions to introduce themselves to their groups, decide who will act as the group facilitator for the phase, and decide who will present which paper.

The remaining four weeks of each phase are student-led, with the first 15 minutes of each 65-minute long session carved out for relationship building and the remaining 45 minutes for paper presentations. Each student is responsible for presenting one paper during each 5-week phase and for skimming and submitting questions for the presenter during other weeks, which was graded in the 1-credit version of the program. In the typical case of two presenters per week, each paper presentation is roughly 5-7 minutes, followed by 15-20 minutes of discussion. Finally, there is an end-of-quarter session held in-place of a final exam. This session is another chance for students to ask more questions about undergraduate research and to provide students with guidance on how to succeed in a research lab.

3.2 Data Collection and Analysis

3.2.1 Participants. The course was advertised through social media, engineering newsletters, advising, partnering faculty, and programs for underrepresented students. There were no prerequisites, and all students were accepted off the waitlist. In the 2022-23 academic year, there were a total of 42, 66, and 54 students enrolled at the end of the course in Fall, Winter, and Spring, respectively. Students filled out an intro and exit survey at the beginning and end of the quarter and theme feedback surveys after each of the two phases. For the purpose of analysis, the sample was restricted to the 136 students who had both intro and exit surveys that could be matched. Of these students, 49.2% were female or non-binary, 8.0% were Black/African American, Hispanic/Latino/Spanish origin, or Native Hawaiian/Pacific Islander, 7.4% were transfer students, 17.5% were first-generation college students, and 15.4% were non-engineering majors. This study was conducted with the approval of the Institutional Review Board at the University of California: Santa Cruz (IRB Approval Number: 2979).

3.2.2 Measures and analysis. We carried out a mixed methods study in which we defined and analyzed quantitative measures informed by our formative study and then used qualitative data to develop a richer picture or to contextualize quantitative findings. The theme feedback survey asked students to rate, on a 5-point Likert scale, several statements on their experience of the reading group (e.g. "*I discovered applications I personally care about*", "*I got new ideas for my personal projects*", "*I gave or received academic or career support*", "*I gave or received emotional support*", etc.), defined based on qualitative observations described in the formative study on ERGs. Descriptive statistics and frequencies were used to summarize these responses.

The intro and exit surveys measured a variety of things before and after the ERG experience, including 1) motivation for participating in research, 2) anticipated experiences in research, 3) interest in various job types, 4) confidence in abilities for various skills, and 5) career identity formation questions based on the Utrecht-Management of Identity Commitments Scale (UMICS) instrument, measuring levels of commitment, deep exploration, and reconsideration of educational and career goals [17]. Specific statements for these Likert questions can be found in **Figure 1**. A repeated measures t-test was used to examine mean score differences.

Surveys also included open-ended responses asking them what they liked, disliked, or suggested about the ERGs and also asking them to elaborate on their responses. Since the descriptive statistics on ERG experiences were developed based on qualitative data already discussed in prior work, we did not analyze qualitative data on these. Instead, we focus on conducting a thematic analysis on the value or benefits that students derived from ERGs, using an inductive approach to surface themes emerging from the data [9].

In our process, the second author first read through the qualitative data (the responses to open-ended survey questions) several times to familiarize herself with it and then conducted initial coding of the responses to form preliminary themes and subthemes. These were discussed with the second and third authors who then independently coded the data using these preliminary themes. These were then discussed in-depth together with the last author to address discrepancies, compare the emerging themes with the quantitative data, and refine the themes and subthemes to better communicate the shape of the data and connections with quantitative observations. The data was then recoded by the second, third, and fourth authors using this final set of themes, with all data independently coded by at least two people, and disagreements discussed and resolved. The final set of themes and subthemes can be found in **Table 1**.

Additionally, beyond analyzing values or benefits derived from ERGs, there were also a few initially surprising quantitative findings (e.g. around feelings of being an outsider or reconsideration of educational or career goals) that we sought to better understand through further triangulation of quantitative and qualitative data, as will be discussed later.

3.3 Limitations

One important caveat when interpreting our results is that while all our data was collected during the ERG experience and before any subsequent research experiences, it is important to interpret the benefits we found in connection with the fact that students were guaranteed to be able to join follow-up group research projects after participating. In other words, it may not be accurate to attribute the benefits solely to ERGs, but rather to ERGs that are connected to opportunities for deeper follow-up experiences.

We also note that the p-values reported have not been corrected for multiple comparisons (e.g., Bonferroni correction), and we have included results with p-values less than 0.10, in addition to the more common cutoff of $p<0.05$. This approach was adopted due to our small sample size and the early stage of the program's implementation and evaluation. The primary goal of this analysis was to explore potential impacts and gather initial results, however preliminary, to guide further research and program refinement. While this method increases our chances of Type I errors, we accepted this trade-off to avoid potentially overlooking subtle but important effects (Type II errors), which are particularly critical in this early stage of the program. Our qualitative findings provide additional support for some of the observed quantitative trends, suggesting that these initial results reflect meaningful patterns worthy of further investigation. As our program matures and our sample size increases, we plan to employ more stringent statistical methods, focusing on confidence intervals and effect sizes to ensure the reliability and validity of our findings.

4 Quantitative findings around the ERG experience and outcomes

4.1 The ERG Experience: Prevalence of Qualitative Observations in the Formative Study

Student survey data showed that students enjoyed the course and also demonstrated that the qualitative observations made in prior formative work [45] around intellectual stimulation and relational support were not just anecdotal, but were experienced by many students.

4.1.1 Students enjoyed the course. Students liked the course. Responses to a net promoter score (NPS) question in the exit survey ("*On a scale from 1-10, how likely would you be to recommend CMPM 15 to other students?*") had a mean of 8.5 ($\sigma = 1.31$), with 69.1% of students rating a 9 or 10 (a "promoter" in the NPS scale). When looking at students who expressed "somewhat agree" or "strongly agree" in 5-point Likert scale questions in the theme feedback survey on various experiences, an impressive 95.2% of students "enjoyed reading and sharing insights" from their papers, 93% "enjoyed the weekly paper discussions", and 85.2% "enjoyed the get-to-know-you questions".

4.1.2 Students experienced intellectual stimulation. We found that the intellectually stimulating or relational experiences that had been observed in qualitative findings within the formative study were, in fact, experienced by many students, showing that ERGs provide important academic and social experiences for students. Specifically, in statements around intellectual simulation, 84% "discovered applications I personally care about", 63.3% "got new ideas for my personal projects", and 95.1% "got exposed to ideas that I found fascinating".

4.1.3 Students experienced relational support. Statements around relational experiences were not as high, but considering that students were only meeting 1 hour a week for 5 weeks in a given phase, we see these results as still surprisingly positive: 80% "developed good relationships with others in my group", 56.7% "gave or received academic or career support", and 42.3% "gave or received emotional support". Additionally, 50.3% "got to know someone in a research lab I got to ask questions of" and 71.9% "encouraged or [were] encouraged to pursue interests/opportunities".

4.2 ERG Outcomes: Statistically Significant Changes Between the Intro and Exit Survey

We also found statistically significant outcomes related to intellectual development, motivations for joining research labs, sense of belonging for underrepresented students, and the development of career identity between student responses in the intro survey (before the start of ERGs) and in the exit survey (at the end of ERGs).

4.2.1 Intellectual development and research-related skills. In responses to a 5-point Likert scale question to "Please rate the extent to which you agree or disagree with the following questions" from strongly disagree to strongly agree, we found a statistically significant increase in "I am satisfied with the extent of my intellectual development since enrolling in this university" (3.46 to 3.75, p=0.003).

When responding to "I am confident in my ability to..." on a 5-point Likert scale from strongly disagree to strongly agree, we found an increased confidence in various academic research-related skills such as their ability to "read research papers" (4.05 to 4.31, p=0.001), "present ideas clearly and effectively" (4.24 to 4.36, p=0.035), and "share the impact of my field on society with others" (4.17 to 4.33, p=0.037). We also observed a positive trend in their ability to "engage in discussions on ideas in my field" (4.24 to 4.38, p=0.053), though this did not reach an alpha of $p<0.05$.

4.2.2 Better alignment with faculty when joining research labs. We observed changes in students' motivations and expectations for joining research labs. When asked "If you were to participate in research sometime during college, which of the following would be your goal or motivation in doing so?" on a 5-point Likert scale from strongly disagree to strongly agree, we found a decrease in motivation to join research in order to "Explore what research is like" (4.60, 4.45, p=0.037) and to "Explore or work on something interesting" (4.86, 4.69, p=0.002). We believe that this was due to the ERG experience already satisfying (for some students) the student need for exploration. In contrast, there was a positive trend in motivation to join research in order to "make a research contribution and publish it" (4.15, 4.30, p=0.065), aligning the students' motivations closer to faculty goals. Students also seemed to developed a better understanding of the (unfortunate) realities of research, with a decrease in an expectation that their research experience would entail significant "mentorship from a faculty member" (2.88 to 2.71, p=0.050). It is important to note however that both of these trends did not reach an alpha of $p<0.05$ and need to be investigated further.

We also note that though this cannot be solely attributed to ERGs (which cannot by themselves affect the available opportunities for UREs), 72.2% of participating students applied and were offered a position in "group research projects" that ERG faculty sponsors provided (note: there could be additional students that applied to positions outside of the group research projects we helped to coordinate).

4.2.3 Increased sense of belonging for minorities. We saw evidence of an increased sense of belonging for minorities. When asked "Please rate the extent to which you agree or disagree with the following questions" on a 5-point Likert scale from strongly disagree to strongly agree, there was a positive trend in "I feel a sense of belonging in my major or field" for female students (3.82 to 4.02, p=0.096) as well as for non-white/asian students (3.67 to 4.27, p=0.007).

4.2.4 Feelings of being an outsider and making things up for non-minorities. Not all results were positive. Unlike females and non-white/asian students who experienced an increased sense of belonging, non-minorities did not experience an increase. Instead,

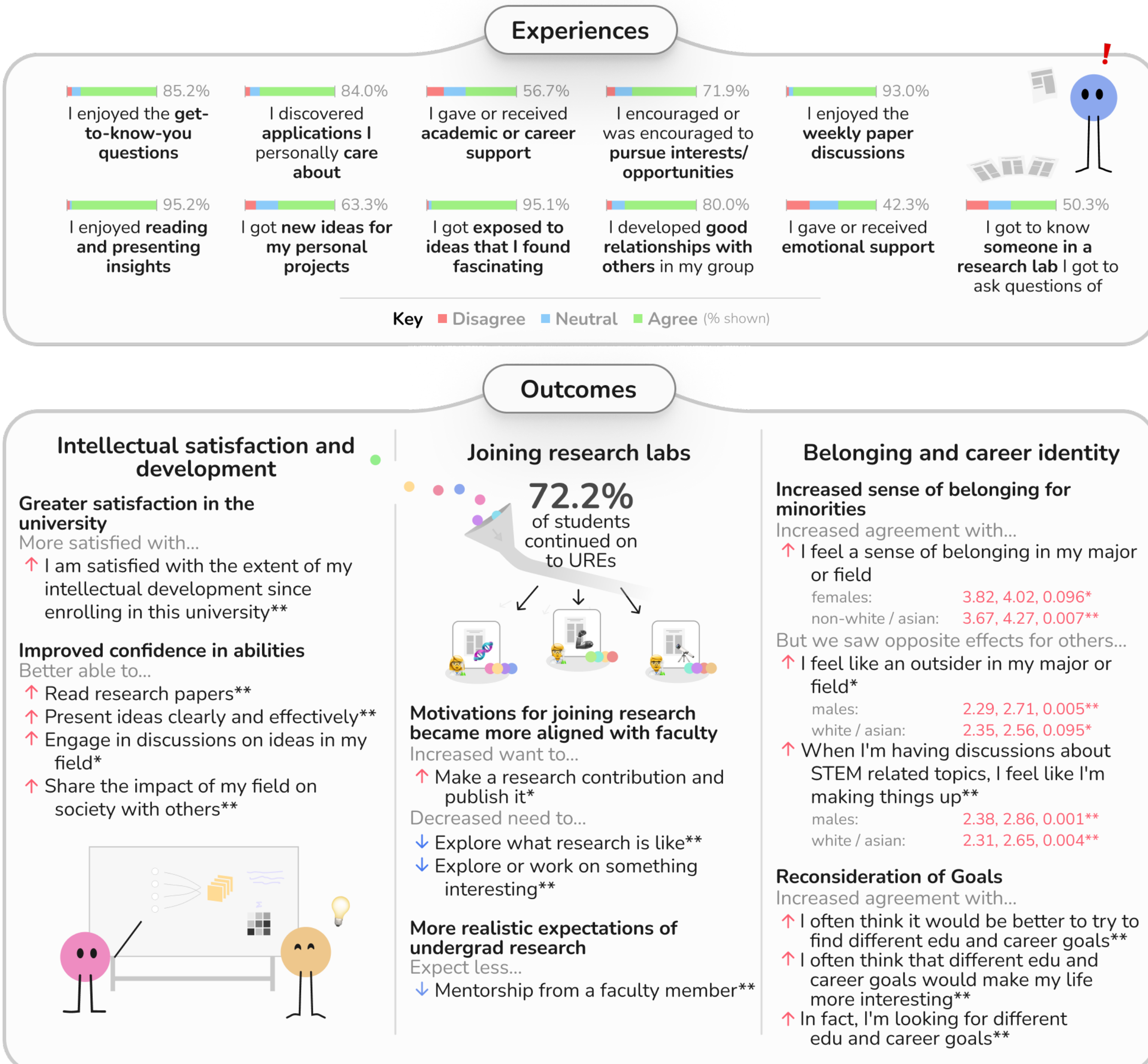

Figure 1: Exploratory Reading Group experiences and outcomes. Items under the "Experiences" panel were taken from the exit survey and were on a 5-point Likert scale with 1=strongly disagree, 3=neutral, and 5=strongly agree, with an additional "not applicable" option. As shown, "Disagree" (red) combines "Disagree" and "Strongly Disagree"; "Agree" (green) combines "Agree" and "Strongly Agree". Items under the "Outcomes" panel represent changes between Intro and Exit Surveys for each quarter. Asterisks indicate *$p \leq 0.10$ and **$p \leq 0.05$. Red arrows indicate an increase from pre to post whereas blue arrows indicate a decrease. Labels in the figure are shortened for brevity.

there were strangely counterintuitive increases in "I feel like an outsider in my major or field" for males (2.29 to 2.71, p=0.005) and white/asians (2.35 to 2.56, p=0.095), though the latter did not reach the level of p<0.05, and increases in "When I'm having discussions about STEM-related topics, I feel like I'm making things up" for males (2.38 to 2.86, p=0.001) and white/asians (2.31 to 2.65, p=0.004).

We tried to dig into this further to understand potential causes, but we did not have open-ended response questions that specifically touched on this. We considered whether non-minorities might have started off overly confident (and then were humbled later), but the data did not seem to support this. When examining qualitative responses on overall experiences (for individuals who experienced an increase in feeling like an outsider or feeling like they were making things up), we found multiple cases in which students reported being overwhelmed by technically dense papers, i.e. papers that have a lot of mathematical syntax and proofs. However, an examination of reading groups that contained more technically dense papers did not support this. At the same time, it did seem like negative experiences had some connection to particular reading groups.

When plotting mean scores on the belonging items grouped by participation in different reading groups, we observed three groups with relatively higher increases in feelings of being an outsider: educational technologies, explainable AI for autonomous vehicles, and sustainable sensor networks. If one runs a repeated measures t-test on this sub-population (students who participated in at least one of these groups), one does see an increase in "I feel like an outsider in my major or field" (2.28 to 2.79, p=0.013) and "I feel like I'm making things up" (2.28 to 3.05, p=0.001), but these results have to be taken with a significant grain of salt as we formed this sub-population only afterwards, based on identifying which groups had higher increases. We also note that the latter two reading group topics had more technically dense papers, but the former did not (and there were other technically dense reading groups where an increase was not observed). Further research will need to be carried out to better understand what was observed here.

4.2.5 Increased reconsideration in career identity formation. A final change we observed is that students increased their level of reconsideration in the UMICS instrument for career identity formation [17]. Students were asked "Below are a number of questions about you and your educational and career goals. In each case, select the option that most closely matches your opinion" and were told to respond on a 5-point Likert scale from completely untrue to completely true. We found an increase in all three questions that related to the reconsideration dimension of UMICS: "I often think that it would be better to try to find different educational and career goals" (2.32 to 2.58, p=0.045), "I often think that different educational and career goals would make my life more interesting" (2.31 to 2.70, p=0.005), and "In fact, I'm looking for different educational and career goals" (1.68 to 1.92, p=0.037).

While this initially looked alarming to us (were ERGs causing students to reconsider computing?!), looking at qualitative responses (to "Has CMPM 15 led you to reconsider your educational and/or career goals or shaped them in any way? If so, please explain what aspects you are reconsidering or what aspects have been shaped?") showed that these were largely positive dynamics of reconsideration, e.g. with students expressing having new interests in research careers (most common), students thinking more deeply about their careers due to exposure to topics that intrigued them, or students coming to understand what they really loved. These can be seen in the following illustrative quotes:

> *"Yes, because I have become a little more interested in getting a research job. I didn't think I would want to do research when I was in high school, but now I think that it is very interesting, and it's a possibility for my future." (P120, Male)*
>
> *"CMPM15 had made me more interested in my major, which I was losing interest on before joining CMPM15." (P57, Male)*
>
> *"Coming into this class, I was unsure if I wanted to pursue a TIM major or environmental science, and this class has helped me figure out that I enjoy enviro science much more. The sustainability readings were incredibly interesting, and I am more confident that I don't want to pursue CS (sorry, this sounds mean, but it's actually a good thing!)." (P35, Female)*
>
> *"Both of the topics for each phase intrigued me, and it led me to think about my education and career goals more." (P21, Male)*

It was interesting to us that an increase in reconsideration in career identity formation could be a positive rather than a negative outcome of exploration. We discuss this further in the Discussion section (**Section 6.3**).

5 A Qualitative View of the Value Students Derived

Our qualitative analysis of the value that students derived from ERGs backs up and further contextualizes our quantitative findings. We identified five major themes describing how students: gained research-related skills, expanded their view of computing and the research world, grew more confident in and obtained opportunities for research, developed a better understanding of their interests and career goals, and built new relationships and obtained peer support. These themes, along with the subthemes and an illustrative quote, are shown in Table 1.

5.1 Gained skills in reading, presenting, and discussing research

Our first theme centered on participants describing how they learned to read and understand research papers, improved their presentation and public speaking skills, and learned to discuss and interact in groups. These directly relate to the quantitative increases we observed in students' confidence in several research-related skills such as reading research papers, presenting ideas, and engaging in discussions on ideas (**Section 4.2.1**).

5.1.1 Learned to read and understand research papers. Many students reported gaining experience reading and understanding research papers, developing *"their skills of going through research material" (P126, Female)* and becoming *"no longer intimidated when seeing a research paper" (P126, Female).* Two students elaborated that,

> *"I feel that I began to understand how to pinpoint the most important aspects of papers in order to properly convey the ideas presented to those who haven't read a paper..." (P158, Female)*
>
> *"I learned techniques to read research papers without knowing the small details of how the algorithms and math work." (P127, Male)*

Table 1: Themes and sub-themes related to the value students derive from ERGs identified through our qualitative analysis.

Theme	Subtheme	Illustrative Quote
Gained research-related skills	Learned to read and understand research papers	"I learned techniques to read research papers without knowing the small details of how the algorithms and math work."
	Improved presentation and public speaking skills	"I was able to communicate and enhance my research skills through the presentation as well as active listening through others' presentations."
	Learned to discuss and interact in group settings	"Being able to have discussions with other students on these topics as well really helped bring about new perspectives to light, as everyone shares their own thoughts and ideas. I think this level of collaboration and discussion really helps us students as aspiring engineers and researchers."
Broadened view of computing and research	Learned about diverse topics in computing research	"I think [the ERG program] is a great way for those in the field to get a little taste of various STEM topics without having to dive fully into a whole course."
	Developed understanding of the research process	"I think that it is important to give students these opportunities to learn more about research and make it accessible. It makes the process less intimidating..."
Increased confidence and opportunities for research	Gained confidence in research materials and process	"My main goal for joining the class was to develop my skills of going through research material and making sense of it, then using that data to draw conclusions. This is something that I definitely achieved in this class, I'm no longer intimidated when I see a research paper anymore"
	Obtained opportunities to join research experiences	"This class is by far the most accessible way (as far as I am aware) to obtain a research opportunity. Without this class, then the only way to obtain research is to go around and ask Professors and by word of mouth."
Developed understanding of interests and career goals	Developed clarity about their interest in research	"Before I took this course, I always thought that scientific research was boring and complicated. But I found it to be a very interesting and fulfilling subject. In addition, these studies can help us better understand the world!"
	Developed clarity in their interest in computing and topics within computing	"[The ERG program gave me] a little taste of various STEM topics without having to dive fully into a whole course. I was really interested in Machine Learning when I first entered but I realized I love development lots more."
Enhanced relationships and peer support	Built relationships, connections, and expanded network	"I have been exposed to a whole new world of undergraduate research, and to professors who would love to have a few more helping hands around their lab."
	Obtained peer advice on navigating the university	"The primary benefit I got from participating in reading groups was wisdom from older students. A lot of the times if we had extra time, we would talk about CS classes and they would recommend how to prepare for a class or which teacher to take. Also, participating in research groups allowed me to receive insight on current knowledge from these older students."

Students also described developing critical and analytical thinking skills in connection with reading and understanding research papers. For example, two students noted:

> *"The primary benefit I received from the reading groups was learning to critically read, analyze, and discuss research papers. This was fairly new to me, so it was a useful new skill to learn that could benefit me in the future as I explore research." (P136, Female)*

> *"The way of computation has changed a lot because I never had the habit of critical thinking about why it works in that specific manner. The readings for this class helped me a lot to develop that habit." (P151, Male)*

5.1.2 Improved presentation and public speaking skills. Many students highlighted that ERGs enhanced their presentation and public speaking skills. They overcame initial hesitations, learned to present their ideas assertively, and grew more confident in things like sharing their analyses. Two students shared that,

> *"I was able to communicate and enhance my research skills through the presentation as well as active listening through others' presentations." (P101, Male)*

> *"I was able to get out of my comfort zone and be able to present without having the worry." (P123, Male)*

5.1.3 Learned to discuss and interact in a group setting. Students described how they *"learned a lot about collaboration and communication" (P175, Female)* and frequently described engaging in constructive discourse with peers that provided a wealth of varied perspectives and opinions. Two students stated,

> *"Being able to have discussions with other students on these topics as well really helped bring about new perspectives to light, as everyone shares their own thoughts and ideas. I think this level of collaboration and discussion really helps us students as aspiring engineers and researchers." (P200, Female)*

> *"This has made me eager to participate in group work since any very difficult concept can be made easier by mutual explanation." (P34, Male)*

5.2 Expanded their view of computing and the research world

The second theme we identified centered on participants talking about how ERGs expanded their view of computing and the research world, which we see as relating to the increase in satisfaction with intellectual development (**Section 4.2.1**) and decrease in describing "Explore what research is like" as their motivation for joining research labs, because the ERG experience was satisfying students' exploration needs (**Section 4.2.2**). The expanded view of computing that they obtained also explains increased confidence in students' ability to "share the impact of their field on society with others" (**Section 4.2.1**).

5.2.1 Learned about diverse topics in computing research. Many students stated they learned about diverse research topics in computing research. They believed that ERGs *"gave them a good exposure to the world of computer science research" (147, Male)* and *"opened their eyes to different types of research with different goals" (P58, Female)* with a *"relatively low commitment" (P123, Male)*. Quoting three participants,

> *"As a Computer Science major, I'm always impressed with how the world of computer science can be applied to pretty much everything. This was a big takeaway I learned from [the ERG program]. Something like disabilities or learning about the human brain can be subjects that do not seem like computer science can be used, but it was!" (P130, Female)*

> *"I think [the ERG program] is a great way for those in the field to get a little taste of various STEM topics without having to dive fully into a whole course." (P59, Male)*

> *"My motivation was to get involved within research in a topic that deeply interests me and prepares me for my career. This has completely been the case with this course, I was exposed to a field that I was not aware of all the research being done even on our campus and within my own vicinity as well." (P158, Female)*

5.2.2 Developed understanding of the research process. Students developed an understanding of the research process. They *"learned how research works from the very beginning till getting specific results" (P150, Female)* and *"many of their questions about research were cleared up" (P145, Male)* by ERGs. Two students pointed out,

> *"Joining research opportunities, especially as a freshman, can be very difficult because there's no clear pathway to join them. For me, it was scary to even think about getting involved in research because I felt like I had no experience and I didn't even know what I wanted to do...got the opportunity to see what research is like, and it broke down the process for me, making it seem less scary..." (P63, Female)*

> *"I think that it is important to give students these opportunities to learn more about research and make it accessible. It makes the process less intimidating and I hope/ wish that the Psychology department had the same opportunities." (P58, Female)*

5.3 Increased confidence and obtained opportunities for research

The third value that students derived from ERGs was increased confidence in the research process and opportunities they obtained to join research experiences. These increased opportunities were evidenced in the fact that 72% of students continued on into UREs (**Section 4.2.2**) and their increased confidence in the research process could potentially have contributed to the quantitative increase we saw in a motivation to join research in order to "make a research contribution and publish it" (**Section 4.2.2**).

5.3.1 Gained confidence in research materials and process. Students said they gained confidence in the research process *"when dealing with research topics/materials" (P187, Female)*. Before the class, even the thought of the research and joining a research project was intimidating for many students since *"it sounded very complicated and hard " (P82, Female)*, and they thought they had no experience. However, after reading and learning more about the research process, they *"no longer felt intimidated." (P126, Female)* As mentioned by a participant,

> *"My main goal for joining the class, was to develop my skills of going through research material and making sense of it, then using that data to draw conclusions. This is something that I definitely achieved in this class." (P126, Female)*

5.3.2 Obtained opportunities to join research experiences. Many students expressed that a significant motivation for taking this course was to obtain the opportunity to *"secure a spot in a research lab for next quarters" (P195, Female)*. As described by two participants,

> *"I think that this class presents a unique opportunity for students to get their foot in the door when it comes to doing research as an undergraduate student and that not having this class would take away that opportunity for a lot of people." (P137, Male)*

> *"This class is by far the most accessible way (as far as I am aware) to obtain a research opportunity. Without this class, then the only way to obtain research is to go around and ask Professors and by word of mouth." (P167, Male)*

5.4 Developed a better understanding of interests and career goals

The fourth theme we observed was that students described how ERGs helped them develop more clarity in their interest in computing, in research, or in topics within computing. This was also reflected in the quantitative increase in students' reconsideration of their educational and career goals (**Section 4.2.5**). The ERG experience fostered new interests in research careers, encouraged deeper reflection on career paths, and helped students discover passions.

5.4.1 Developed clarity in their interest in research. Students described the course as an excellent opportunity to explore whether research *"was something they were into." (P4, Male)* As expressed by two of them,

> *"Before I took this course, I always thought that scientific research was boring and complicated. But I found it to be a very interesting and fulfilling subject. In addition, these studies can help us better understand the world!" (P211, Female)*

> *"Before this class, I thought doing research was boring and full of math. Because most of the papers use data to prove their idea. But actually, doing research is not only data things, it could include many different parts and working on an interesting part." (P191, Male)*

In a few cases, the clarity they developed was in the opposite direction, with a participant saying that *"It made me understand I have no interest in research" (P113, Female)*

5.4.2 Developed clarity in their interest in computing and topics within computing. Students expressed that ERGs helped them narrow down what they *"wanted to explore further in the near future" (P93, Female)* and tailor their energy to *"efforts that would be better suited to what they want to work on." (P103, Female)* They expressed having no idea what some topics were about before this class but developing an interest in them afterwards. As described by two of them,

> *"The reading groups changed my interest from UI/UX design to user research design. The papers gave me a broader understanding of the roles required in the research process, and I believe my goals aligned better with a career in user research. The readings helped me consider what labs I would like to be in based on the career that best suits me." (P23, Female)*

> *"[The ERG program gave me] a little taste of various STEM topics without having to dive fully into a whole course. I was really interested in Machine Learning when I first entered but I realized I love development lots more." (P59, Male)*

5.5 Built new relationships and obtained peer support

The final theme we observed was that participants described building new relationships, expanding their network, and obtaining peer support in navigating the university. This relates to the relational support that students described experiencing (**Section 4.1.3**) and we believe could have contributed to the increased sense of belonging for minorities that we also observed (**Section 4.2.3**).

5.5.1 Built relationships, connections, and an expanded network. Students expressed that they met new people, including their peers and professors, *"made connections and networks with them," (P136, Female)* and *"made friendships." (P59, Male)* We note that faculty did not actually join the reading group sessions since the reading groups were student-run. However, faculty and some representatives from their labs were available on a Discord channel to answer students' questions. As mentioned by three participants,

> *"These opportunities are also really valuable to make connections with other students and with faculty, who can provide great support and who you can learn from, both in an academic and non-academic context." (P136, Female)*

> *"The networking aspect of this class was what I needed most. I feel that I made a solid few connections that could help me to take my career to the next level through mentorship of some kind." (P8, Female)*

> *"I have been exposed to a whole new world of undergraduate research, and to professors who would love to have a few more helping hands around their lab. " (P139, Male)*

5.5.2 Obtained peer advice on navigating the university. Students described the course as an excellent opportunity where they *"met like-minded students who were involved in the same or similar majors to them," (P16, Male) "had similar interests and the same academic aspirations," (P129, Male)* and could *"get wisdom from older students." (P202, Male)* Two students expressed,

> *"Talking with other students who share similar goals and majors was very beneficial. Just hearing about things they were doing or classes they were taking was helpful. This also contributed to our conversations about the papers we were reading." (P199, Male)*

> *"The primary benefit I got from participating in reading groups was wisdom from older students. A lot of the times if we had extra time, we would talk about CS classes and they would recommend how to prepare for a class or which teacher to take. Also, participating in research groups allowed me to receive insight on current knowledge from these older students." (P202, Male)*

6 Discussion

In this section we start by discussing our findings on ERG outcomes and experiences, how they compare to the benefits found in UREs, and to what extent ERGs help to overcome barriers to UREs. We then reflect more broadly on what our results say about the usefulness of lightweight, relational learning experiences more generally for designing ecosystems. Finally, we return to some of our observations around career identity formation to suggest future research directions for broadening participation to computing.

6.1 Exploratory Reading Groups and Barriers to UREs

As described earlier, one of the motivations for this study was to evaluate the benefits of ERGs to understand to what extent a lightweight (and thus, more scalable) research experience centered on reading and discussing papers could provide some of the benefits typically obtained through more time-intensive undergraduate research experiences (UREs). We found evidence that ERGs provide many of these benefits, at least to some extent, and that they help to overcome many barriers to future participation in UREs.

Our results, aligning with academic literature on the benefits of UREs [20, 21, 48, 52], demonstrate that students who participated in this program developed important soft skills such as becoming more confident in reading, presenting, and discussing research (**Sections 4.2.1 and 5.1**), allowed them to broaden their understanding of computing research, and perhaps most importantly, helped foster a collaborative and supportive community (**Sections 4.1.3 and 5.5**). This aspect of ERGs is particularly noteworthy, as it addresses a fundamental barrier to URE participation: the perceived lack of support and the intimidation factor [49]. Moreover, the sense of community and shared learning provided by ERGs fosters a growth mindset, equipping them with the tools to overcome the challenges inherent in conducting research.

ERGs are not replacements for UREs, however, as there were still some benefits that are clearly provided by UREs but not provided by ERGs. ERGs have not been shown to equip students with new technical skills — a fundamental component of UREs [48]. The broad, scalable nature of ERGs focuses on a wider exploration of research topics rather than fostering a deep, immersive understanding or significant technical experiences. Although ERGs expand accessibility and introduces a diverse set of research topics to a larger student body, it may not satisfy students who have already pinpointed their research interests and are seeking an intensive, specialized experience to enhance their resumes and deepen their expertise. This may also be why we didn't see evidence of an increased probability to pursue graduate studies, something that UREs have been shown to provide [20]. We also add the caveat that our data does not allow us to compare the strength of the benefits, which could be greater for the more time-intensive UREs.

We also observed many ways in which ERGs help to facilitate entry into more traditional UREs by overcoming different barriers experienced by students and faculty that stem from misalignments in systems, goals, and expectations [55]. At the systems level, barriers can stem from the lack of systematized pipelines for recruiting or applying, and the lack of classes that expose students to research, resulting in a lack of student awareness and motivation [49]. ERGs provide this exposure, as evidenced by students' improved understanding of the research process (**Section 5.2.2**) and development of research-related skills (**Section 4.2.1 and 5.1**), which potentially also helped with the barrier of perceived lack of readiness/competence [49]. They created a centralized channel through which 72% of student participants obtained URE positions (**Section 4.2.2 and 5.3.2**). ERGs also helped with the mismatch between faculty goals to advance research and student goals to explore. By meeting students' needs for exploration (**Section 5.2.1**) and by helping them clarify their research interests (**Sections 4.2.5 and 5.4**), we found that more students wanted to join UREs for the purpose of making a research contribution rather than just to explore (**Section 4.2.2**). Finally, ERGs helped to align undergraduate expectations of research closer to the realities of research, with more students realizing that they may not be spending a lot of time directly with the faculty mentor (**Section 4.2.2**).

Of course, we do not claim that ERGs address all barriers to UREs, such as physical constraints, lack of faculty incentives, and the time that is still required by faculty to create team and organizational structures to support student participation [49, 55]. But we showed that they do provide many of the benefits UREs provide, and they overcome several barriers that prevent entry into UREs. As we will discuss in the following section, by doing so, they can begin to make change in scalable ways that influence the broader system towards addressing the more challenging barriers that require institutional support and commitment of resources.

6.2 ERGs as a Lightweight, Relational, and Scalable System of Action

In Design Unbound [46], Ann Pendleton-Jullian and John Seely Brown introduce the idea of "systems of action" for designing solutions to complex systemic problems embedded within larger ecosystems. The challenge is that systems are always changing and often not all under your control. Thus, one needs to design solutions that influence the broader ecosystem in ways that effect change. Systems of action are a *"coherent collection of interrelated action-intended components that... work systemically to affect the context of the problem. They scale, enabling small actions to affect a larger social ecosystem through work they do inside the system."*

Expanding opportunities for UREs is an example of a complex systemic challenge that has many barriers at different levels, including system-level challenges like faculty time, reward structures, resources, and institutional support that are not easy to overcome. They often require individuals with sufficient decision-making power or influence or large-scale grants [59] to carry out 'heavy' interventions to create new institutional resources, develop infrastructure, or overhaul curricula [2, 6, 43] in ways that change the status quo in significant strategic ways.

ERGs, on the other hand, are examples of lightweight, relational, and scalable interventions that are (relatively) easy for any individuals to implement. Our reflection is that "easy-to-engage experiences that build relationships" are great components within systems of action because their lightweight and scalable nature makes them easy for key stakeholders (faculty and students) to participate in, and the relationships developed in the process help to influence or smooth frictions in the broader system. These reflections are similar to ones made before [44, 55] but the findings of the current study suggest this more clearly. First, we saw that many people experienced both academic and emotional support, and that this support helped them to make connections and navigate the university (**Sections 4.1.3 and 5.5**). Second, we saw that even relatively lightweight programs can have surprising impacts (**Sections 4 and 5**). When we first began to quantify the program's impact, we were honestly not sure if we would see anything at all since students were only spending 2 hours/week in a quarter-long program, so it was encouraging to see many impacts. Third, we saw that this lightweight approach that started off as a co-curricular activity was able to eventually garner institutional support leading to its current 1-credit form and its ability to help 72% of students join follow-up group research projects.

Thinking beyond just ERGs and UREs, we see opportunities for further research into the design of other lightweight, relational, and scalable learning experiences to help tackle other system-level challenges in education. Small groups are particularly suited to supporting relational experiences, but are not limited to exploratory reading. One could imagine similarly lightweight and scalable exploratory skill-building groups or small groups formed around other shared interests. Small groups that connect community college students and local 4-year colleges could serve as a bridge to ease the transition associated with transferring to a new academic institution. Similarly, groups that connect humanities, social sciences, and engineering students could foster interdisciplinary understanding and collaboration, and small groups that connect students and community members could facilitate collaborations for community-engaged learning in real-world contexts. Beyond small groups, other lightweight structures such as seminar-like events could be designed to be more relational in order to encourage deeper collaboration and discussions. It would be interesting to explore to what extent similar ideas might help to encourage participation and foster relationships that can smooth frictions in the system.

6.3 Exploration, Reconsideration, and Identity Formation

As mentioned in **Section 4.2.5**, we were initially surprised to see that ERGs resulted in increases for all three reconsideration items within the UMICS instrument for career identity formation [17], and were alarmed by whether this indicated that ERGs were leading students to reconsider computing careers. However, a deeper dive into this revealed a more complex dynamic worth reflecting on further for its potential to enrich how we think about student engagement with computing.

Career identity formation in the Meeus-Crocetti model [17] is described as a process with three intertwined dynamics: making commitments, exploring them, and reconsidering them, all of which hopefully work together to help students move towards authentic commitments, i.e. commitments that remain even after meaningful exploration.

We found that participation in ERGs exposed students to the breadth and diversity of computing, challenging and expanding their preconceived notions of what research in the field entails and what falls under the computing umbrella. This exposure can lead to increased reconsideration, but rather than signaling a lack of interest or commitment to computing as a whole, increased reconsideration can also reflect a shift in commitments to other subdisciplines or industry vs. research career paths within computing. Even in circumstances when people do decide to move out of computing, it can be part of a normal healthy process of identity formation (see quotes in **Section 5.4.2**).

In CS education literature on broadening participation, it is fairly common to discuss whether interventions are enhancing STEM/CS identity and sense of belonging [39]. However, very little CS education literature studies the dynamics of identity formation *within* computing, i.e. how students are exposed to different sub-disciplines in computing and how it affects identity formation. Moreover, a systematic literature review on identity in higher computer education research [28] found that among the three types of theories that deal with identity (psychological, socio-cultural, and socio-political), only two papers [34, 35] connected to psychological theories of identity development (Marcia's model that gave rise to the Meeus-Crocetti model and instruments like UMICS) that deal with how students evolve their commitments through broad and deep exploration and reconsideration. We see this as a promising direction for future research, to better understand and help facilitate the process of identity formation so that students can discover the diverse types of disciplines and career paths within computing and find their authentic fit within it.

This may also require new instruments. For example, UMICS only measures to what extent individuals are engaging with the different dimensions of identity formation (commitment, exploration, and reconsideration), but it does not allow us to understand at what level people are reconsidering their commitments. For example, it may be interesting to ask a hierarchical series of reconsideration questions around whether they are reconsidering computing careers overall or reconsidering their current commitments within computing. Doing so could help to elicit insights into how we can design educational programs and initiatives to support students in navigating the diverse opportunities within computing, ultimately enriching the field with a wider and more diverse range of people, perspectives, and expertise.

7 Conclusion

This paper conducted a summative analysis of the Exploratory Reading Group (ERG) program, revealing not only that it can provide similar benefits seen in traditional UREs, but also its role in widening access to research opportunities in the computing field. Our findings revealed statistically significant increases in participants' satisfaction with their intellectual development, a heightened sense of belonging among underrepresented groups, and enhanced confidence in engaging in the field of computing. The insights from this study also have implications for the design of undergraduate research experiences and the broader goal of increasing diversity within computing. By reinforcing the value of exploratory, peer-led models like ERGs, this work calls for a reevaluation of traditional pathways into research and highlights the importance of fostering environments that celebrate exploration and personal growth.

Our analysis contributes to the computing education literature by highlighting how low-commitment, relational, student-led interventions can facilitate early engagement in research, particularly for underrepresented students. The program's success in improving relational dynamics and academic self-efficacy among participants points to the potential of ERGs in addressing persistent challenges related to diversity and inclusion in STEM fields. In the spirit of reproducibility and expansion of the program, we have provided a detailed playbook for educators wishing to implement exploratory reading groups at their institution [1].

Looking forward, we are excited to see other researchers build on our work to continue broadening access to UREs. It will be particularly important to explore ways for more faculty to sustainably involve students in group research projects after participating in ERGs. We also see the design of other lightweight, relational, and scalable learning experiences as an interesting direction for tackling other system-level challenges in education, and see important work to be done on identity formation and career exploration within computing education to help students navigate the diverse landscape of computing towards cultivating a diverse, empowered generation of computing professionals.

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A Appendices

A.1 Additional Tables

Table 2: Demographic data for students who completed pre and post surveys

Category	Sample (N=136)
Gender	
Female	66 (48.5%)
Male	69 (50.7%)
Non-binary	1 (0.7%)
Prefer not to say	—
Race or Origin	
Black/African American	1 (0.7%)
East Asian/South Asian	74 (54.4%)
Hispanic/Latino/Spanish Origin	9 (6.6%)
Middle Eastern/North African	4 (2.9%)
Native Hawaiian/Pacific Islander	1 (0.7%)
Southeast Asian	19 (14%)
White	24 (17.6%)
Prefer not to say	*4 (2.9%)*
Missing	—
Are you a transfer student?	
No	126 (92.6%)
Yes	10 (7.4%)
Are you a first-generation college student?	
No	109 (80.1%)
Yes	24 (17.6%)
Prefer not to say	*3 (2.2%)*
What degree are you pursuing?	
Bachelors	124 (91.2%)
Masters	10 (7.4%)
Doctorate	2 (1.4%)

Table 3: Motivation for Participating in Research

Motivation	Pre	Post	P-value
Explore what research is like	4.60	4.45	0.037**
Explore or work on something interesting	4.86	4.69	0.002**
Build skills in an area of interest	4.86	4.79	0.150
Bulk up my resume for industry	4.49	4.57	0.266
Enhance my application for graduate school	3.99	4.02	0.738
Make a research contribution and publish it	4.15	4.30	0.065*

* p-value $\leq$ 0.10
** p-value $\leq$ 0.05

Table 4: Interest in Different Types of Jobs

Job Type	Pre	Post	P-value
College or university professor (teaching focused)	2.57	2.60	0.744
College or university professor (research focused)	2.91	2.88	0.695
K-12 teacher	1.86	1.88	0.872
Research in industry	4.10	4.01	0.305
Researcher in a government lab or agency	3.74	3.67	0.442
A non-research position in industry	4.40	4.42	0.746
A non-research position in government	3.52	3.50	0.841
Entrepreneur (e.g. individual contractor, build a start-up)	3.63	3.66	0.731

* p-value ≤ 0.10
** p-value ≤ 0.05

Table 5: Confidence in Abilities

Ability	Pre	Post	P-value
Read research papers	4.05	4.31	0.001**
Present ideas clearly and effectively	4.24	4.36	0.035**
Engage in discussions on ideas in my field	4.24	4.38	0.053*
Share interesting ideas in my field with others	4.39	4.44	0.479
Share the impact of my field on society with others	4.17	4.33	0.037**

* p-value ≤ 0.10
** p-value ≤ 0.05

Table 6: Agreement with Statements

Statement	Pre	Post	P-value
My knowledge and skills will allow me to help others	4.26	4.26	1.000
My knowledge and skills will allow me to contribute to social issues that are important to me	4.15	4.22	0.283
I feel a sense of belonging in UCSC	4.07	4.07	1.000
I feel a sense of belonging in my major or field	4.01	4.08	0.372
I feel like an outsider in my major or field	2.38	2.60	0.055*
When I'm having discussions about STEM related topics, I feel like I'm making things up	2.34	2.68	0.002**
I am satisfied with the extent of my intellectual development since enrolling in this university	3.46	3.75	0.003**
My academic experience has had a positive influence on my intellectual growth and interest in ideas	4.20	4.23	0.688

* p-value ≤ 0.10
** p-value ≤ 0.05

Table 7: If you were to participate in research during college, how much do you expect that your research experience would entail the following?

Category	Pre	Post	P-value
Collaboration with other peers	3.10	3.16	0.475
Mentorship from a PhD student	2.69	2.77	0.402
Mentorship from a faculty member	2.88	2.71	0.050
Learning things on my own	3.09	3.16	0.386
Learning things from a mentor	3.12	3.05	0.519
Tasks building skills I find interesting	3.27	3.34	0.444
Tasks that are tedious but necessary	2.97	3.13	0.119
Reading and mapping research papers	3.02	3.01	0.884
Writing research results	3.01	3.02	0.875

Table 8: Below are a number of questions about you and your educational and career goals. In each case, select the option that most closely matches your opinion.

Category	Pre	Post	P-value
My educational and career goals give me security in life	4.28	4.30	0.822
My educational and career goals give me self-confidence	4.18	4.16	0.815
My educational and career goals make me feel sure of myself	4.13	4.04	0.397
My educational and career goals give me security for the future	4.26	4.26	1.000
My educational and career goals allow me to face the future with optimism	4.13	4.15	0.813
I try to find out a lot about my educational and career goals	4.38	4.34	0.693
I often reflect on my educational and career goals	4.35	4.37	0.901
I make a lot of effort to keep finding out new things about my educational and career goals	4.20	4.23	0.402
I often try to find out what other people think about my educational and career goals	3.48	3.68	0.109
I often talk with other people about my educational and career goals	3.96	3.92	0.750
I often think it would be better to try to find different educational and career goals	2.32	2.58	0.045
I often think that different educational and career goals would make my life more interesting	2.31	2.70	0.005
In fact, I'm looking for different educational and career goals	1.68	1.92	0.037