"It's usually not worth the effort unless you get really lucky": Barriers to Undergraduate Research Experiences from the Perspective of Computing Faculty

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ABSTRACT

In nationwide efforts to promote computing education, undergraduate research experiences (UREs) have been identified as an effective way to not only motivate research and graduate studies, but to also increase participation and retention, promote disciplinary knowledge and diversity in the field, develop strong soft and technical skills, and integrate students in the community. Yet, despite these many benefits, opportunities for UREs are still limited. And even though the challenge of finding faculty mentors is one of the major barriers, there is still limited research exploring the faculty perspective in greater depth. In this paper, we leveraged an onboarding process for a new program to interview twelve engineering faculty doing computing-related research in a large public research institution about their experiences and perspectives towards UREs. These faculty members ranged in experience from working regularly with many undergraduates to having limited or no prior experience. Our analysis uncovered four main themes on barriers to UREs around the central concept of *misalignment*: misalignments between the educational system and research, misalignments between faculty and student goals, misalignments between expectations of research and reality, and the challenge of getting to and maintaining steady state when trying to create alignment. We conclude by discussing design implications for designing programs and computational ecosystems that scale access to UREs by helping to overcome misalignments.

CCS CONCEPTS

• **Human-centered computing** → **Computer supported cooperative work**; • **Social and professional topics** → **Computational science and engineering education**.

KEYWORDS

Undergraduate Research Experiences, Computing Education, Misalignments, Designing Systems

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1 INTRODUCTION

Undergraduate research experiences (UREs) have been shown to be effective at helping students to gain experience and confidence in computing fields, obtain a deeper understanding of subject material [15, 22], develop a variety of technical and soft skills [16, 34], and foster community and inclusivity in computing research [15, 36]. Yet despite these proven benefits, most computing students in the United States are unable to participate in UREs. One of the significant barriers to increasing access to UREs is the difficulty of finding faculty sponsors willing to involve undergraduates in their research labs [31]. Yet, while this challenge is widely understood to some extent (UREs require faculty sponsors, faculty are notoriously busy, and faculty incentives are not aligned) [5, 8, 32, 40, 46, 47], there is still limited qualitative research providing a *richer picture of faculty perspectives, experiences, and strategies* that could help provide new angles for design and help situate student perspectives in a broader systemic context. As articulated in a National Academies report on UREs [31], *"There is currently a relative paucity of data with respect to the impact of UREs on faculty beyond the role as mentor. Research to improve understanding of how UREs affect faculty is needed because of the potential for unintended impacts to jeopardize the success*

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of efforts to develop and sustain UREs". A rich qualitative picture would be particularly helpful for this, especially in connection to the growing literature in social computing and computer-supported cooperative work (CSCW) on designing computational ecosystems to scale undergraduate research [43, 49]. If one can more richly understand the context underlying barriers to UREs, this may help provide a rich source of ideas for novel approaches to expanding access to UREs.

In this paper, we aim to fill this gap through a qualitative study of the faculty perspective on barriers to undergraduate research. As part of an onboarding process for student reading groups centered on faculty-proposed themes, we conducted twelve interviews of faculty doing computing-related research across multiple engineering departments who were interested in involving more undergraduate students in their research labs, but who had a wide range of prior experience working with undergraduate students.

These interviews sought to develop a broader understanding of what barriers exist, why they remain, and implications for the design of URE ecosystems. Our analysis uncovered four primary themes, all centered around the core concept of *misalignments* (**Figure 1**). First, many barriers stem from the misalignments between the education system and the research system, due to a lack of preparation from the traditional school system, constrained student and faculty time, and a lack of pipelines into UREs. Second, these system-level misalignments led to misalignments in faculty and student goals. Whereas undergraduates were focused on exploring to clarify interests or to build their career, faculty sought to advance research which led them to look for students who could clearly articulate their interests or who had sufficient prior skills. Third, misalignments in expectations and reality often led to failed engagements, both regarding the level of supervision and structure provided in research and the true nature of the work. Finally, faculty members struggled to reach and maintain a steady state within their research labs due to the significant articulation work [39], strategies, and iteration required to overcome misalignments. Faculty must build and maintain team and organizational structures to manage the lab amidst a constant stream of students coming and going, each of which may have unique contexts that require shifting strategies. Due to the transient nature of students and the lab, faculty must continually iterate and rebuild structures. The four core themes of our findings provide a new theoretical framework for characterizing systemic challenges through examining misalignments in systems, goals, and expectations, and the effort involved to create and maintain alignment. In what follows, we discuss related work (**Section 2**), describe our study methods (**Section 3**), and detail our findings for each of our four themes (**Sections 4-7**). We conclude by discussing implications for designing programs and computational ecosystems for UREs that help to reduce, eliminate, or better manage misalignments (**Section 8**). In the Appendix, we also present a narrative that weaves together faculty quotes to synthesize barriers that undergraduates face across the entire URE journey (**Appendix A**).

2 RELATED WORK

2.1 Barriers to Undergraduate Research Experiences

Much of the literature on UREs centers on evaluating *past* undergraduate research experiences to understand benefits or to reflect on what contributed to positive or negative experiences [5, 17, 50], e.g., for evaluating the impact of UREs on computing degree attainment for underrepresented minorities [17] or pointing out unconscious biases that faculty might have and synthesizing tips on how to structure a CS research experience [5, 47]. Because the focus in such studies is on improving *existing UREs*, this means that they only lightly touch on *barriers to future UREs*, e.g., while discussing the significant amounts of time faculty felt was required for participation and how this can take away from scholarly output and thus disincentivize future participation [5, 12, 13, 20, 28].

As called for in a National Academies report on UREs [31], we are motivated to understand how one might radically expand the number of future UREs such that "eventually all undergraduates are afforded this kind of learning opportunity" due to the growing recognition of UREs as "one of the high-impact practices that can dramatically influence undergraduate education". Doing so requires a focused understanding of barriers, especially from the faculty perspective due to the lack of faculty mentors being the most commonly identified bottleneck to significant expansion of UREs.

A few studies have begun to focus on barriers to UREs. These include a case study at Northern Arizona University that described 5 changes they undertook to address 5 identified barriers that resulted in a significant increase of involved faculty from 60% to 94% [46], and a 2021 systematic literature review on "barriers to accessing undergraduate research for computing students" [35] that synthesized and interpreted findings from studies that touched on barriers (even if barriers were not the focus) to identify the following barriers: physical resource issues, lack of time, lack of faculty incentives, perceptions of lack of student readiness, student lack of interest or motivation, student financial constraints, lack of undergraduate research in courses or issues implementing such courses, social deterrents, negative faculty perceptions regarding student capacity and competency, lack of institutional commitment, student lack of awareness, lack of faculty diversity, and discipline-specific barriers.

Three large-scale surveys have sought to produce a quantitative picture of faculty barriers, surveying 71 faculty at a large state university in Georgia [8], 239 faculty at three primarily undergraduate institutions [30], and 106 statistics faculty recruited through forums for statistics associations [32]. These showed that faculty perceived the benefits of UREs (for themselves) to be primarily around the joy of teaching students and helping them succeed; that time was the primary barrier for all faculty; and that faculty who had not supervised undergraduate students in the past year were more likely to view the lack of student preparation and motivation as significant barriers. Buddie et al. also characterized the amount of independence faculty perceived students to be capable of for different tasks and identified factors that would most increase faculty participation (teaching/time credit, summer stipends, and better prepared students).

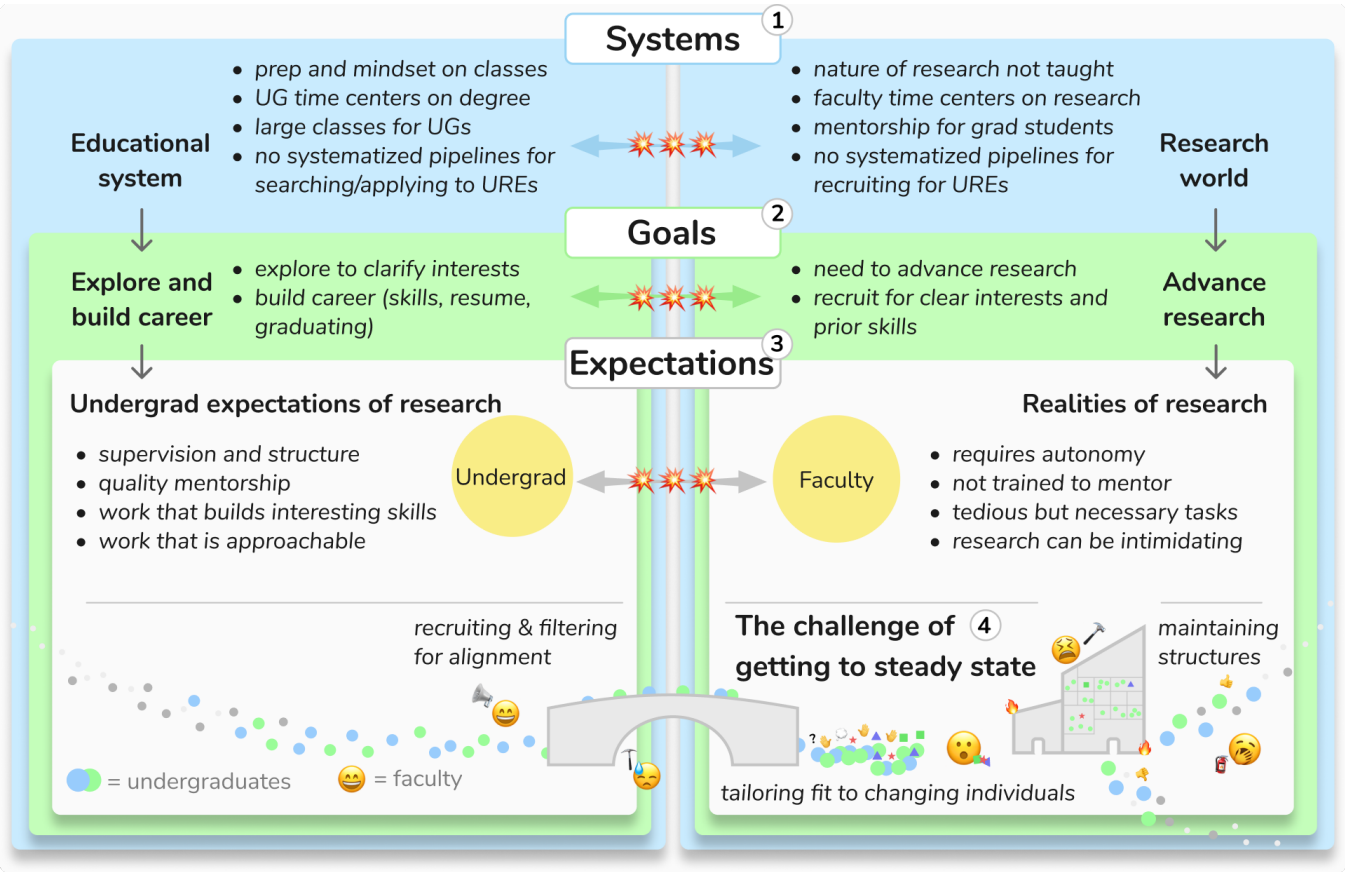

Figure 1: Illustration of the four core themes of our findings. Starting at the systems level (1), misalignments between the educational system and research world introduce significant friction to undergraduates participating in research. These system-level tensions give rise to further misalignments in the respective goals of undergraduates and faculty (2), with students wanting to explore and build their career and faculty wanting to advance research. Misalignments in systems and goals compound to cause misalignments between undergraduate expectations of research and the realities of research (3). Finally, faculty encounter the challenge of getting to and maintaining steady state (4) when trying to create alignment by building team and organizational structures to bridge their differing systems, goals, and expectations. Doing so is extremely difficult because they need to be personalized and continually updated with the ever-changing pool of students.

We seek to build on this literature to contribute a *deeper and richer characterization and descriptive narrative of faculty perspectives on barriers to UREs* through a qualitative study with faculty participants. Rich qualitative accounts are important because they help to identify richer patterns and theoretical connections beyond lists of barriers, and are more generative stimulants for ideation in efforts to design novel solutions. Yet in our literature review, we were only able to identify one other qualitative study centered on understanding faculty perspectives on barriers to implementing UREs. In Brew and Mantai's study [7], which interviewed faculty in a cross-departmental working group focused on implementing undergraduate research programs institutionally, their theoretical focus was on teasing out the diverse ways in which academics talked about undergraduate research meant, and how this might suggest diverse (and potentially lower barrier) ways to engage students in research. The systematic literature review we mentioned earlier [35] identified one other qualitative faculty-oriented study, but this only lightly touched on barriers [41].

We see our study as providing a novel contribution in three ways. First, our theoretical angle synthesizing barriers in terms of misalignments and the continued cost of finding and maintaining alignment is novel to the literature. Second, we are the only study we are aware of that is both focused on faculty perspectives of barriers and that provides "thick descriptions" [18] to add rich generative context. Third, our focus on computing-related faculty at a minority-serving R1 institution (US doctoral universities classified as having very high research activity) with 18,000 undergraduates adds value in reinforcing known results in new contexts, as the vast majority of existing studies (including the case study, the three surveys, and both faculty-oriented qualitative studies) focus on either

non-engineering faculty or on undergraduate/teaching-focused institutions. In **Section 8.1**, we discuss literature on existing ways to expand UREs through the lens of our framework.

2.2 Computational Ecosystems and Scaling Undergraduate Research

One of our motivations for developing a deep qualitative picture of URE barriers, and one of the perspectives we bring into our inquiry, is an interest in designing ecosystems to scale UREs and the role of computation in such ecosystems. Designing computational ecosystems means designing across multiple interacting technological and social components at once to address systemic challenges that may extend across multiple stakeholders at multiple stages of a process [48], e.g., in systems for sustainable food production [27], community-engaged digital civics [3], or scalable undergraduate research [43, 49]. It means considering how one might develop solutions that are not only attuned to existing contexts, but also capable of creating new contexts or influencing continually evolving ones that may not be under one's direct control [2]. We briefly note that our theoretical framing of the barriers to UREs in terms of misalignments is interesting in connection to work on designing for community engagement in digital civics, where researchers have emphasized the importance of understanding relational interactions to support "the work of finding alignment" [4]. Finding ways to scale UREs may similarly require a deeper understanding of areas of misalignment. We note that two past studies, Crowd Research [43] and Agile Research Studios [49], already show the potential of computational ecosystems for scaling undergraduate research. Our goal in this study is to produce a rich understanding of URE barriers that can be valuable for continued efforts to scale and broaden URE access to all students.

3 STUDY METHOD

This project came out of earlier work designing a reading group program to help students explore the creative and socially impactful aspects of computing [33]. While our initial goal was not specifically aimed at supporting UREs, we found that the program ended up sparking interest in research for several participants, and some told us about how the groups ended up helping them land research positions. This led us to the design problem of supporting research pipelines and the need to understand barriers to UREs in greater depth. Since faculty were the bottleneck, conducting a qualitative investigation of the faculty perspective seemed to be a promising first step. Our study centered on the following two research questions. We initially started with just the first of these, adding the second after focusing in on the core concept of misalignments:

> **RQ1**. How do faculty go about recruiting and working with undergraduate students in research, what challenges do they experience in the process, and how does this result in barriers to UREs?
> **RQ2**. What misalignments exist in the broader systems and contexts in which undergraduate research experiences take place, and how do these result in barriers to UREs?

3.1 Study Procedure

Since faculty are busy, we motivated participation by highlighting the potential value of the reading group as pipelines into their research lab. An email was sent to an engineering faculty mailing list of over 100 faculty with interested faculty filling out a survey asking for their teaching position, department, research area and methods, current engagement with undergraduate students, and ideal outcome from proposing a theme. To seed our interviews, we asked them the following question with a 280-character minimum response length: *"What would you share or advise a new faculty who asks you about working with undergraduate student researchers?"*[1]

We collected 17 survey responses from faculty at different stages of their research career, with different levels of engagement with undergraduate students, and in different computing-related research areas across five engineering departments. Of these 17 faculty, 12 responded to the next step: a 30-minute semi-structured intake interview where we first dug deeper into faculty perspectives on UREs (for this study) and then briefly introduced them to the reading group structure (for the program). These final 12 faculty were 33% female, at different stages in their career (6 assistant, 2 associate, 4 full), and in different departments (1 Applied Mathematics, 5 Computational Media, 4 Computer Science & Engineering, 2 Electrical & Computer Engineering). Most worked with between 1-5 undergraduate students each quarter on average (with one working with 10). To preserve anonymity, we do not provided a detailed participant table and use pseudonyms in all quotes that follow.

Our interview guide centered on past experiences recruiting and working with undergraduate students with an eye towards understanding existing perceptions of undergraduate student research and barriers that keep faculty from involving students in research in followup questions[2]. We initially interviewed seven faculty members for our first round of analysis. After converging to our core concept of misalignments, we conducted the remaining five interviews with the same interview guide, but now sensitized towards the theme of misalignments in followups. We also added an additional question that asked them to comment on a statement in a National Academies report describing a goal of expanding opportunities for undergraduate research to all students.

3.2 Data Analysis

The interviews were audio recorded, transcribed, and analyzed through an inductive process that drew on elements of grounded theory [37]. The interviews were designed and conducted by Palea and Lee, followed by open coding of our first seven transcripts to identify the core focus of our analysis, with all five researchers participating and each interview coded by 2-3 team members. We all discussed these initial codes and clustered them together through an affinity diagramming progress, which led us to the theme of misalignments in systems, goals, expectations, and reaching steady state. The team members then went back to recode the interviews with these themes in mind followed by discussions to resolve any disagreements and to discuss potential subthemes.

[1] The extreme busyness of faculty, and the challenge of obtaining faculty perspectives, can also be observed in the non-trivial number of faculty responses that involved submitting filler text or copy-pasting a line multiple times to meet the character count.
[2] The faculty survey and interview guide can be found at: https://datadryad.org/stash/share/ckI14g8ZhwvYoEK3UYQJ_3pLVF7jUqz96fVL6EPAulo

Lee then conducted the final five interviews, followed by analysis by the entire team, this time through a deductive approach focused on the four themes identified in our prior round. The subthemes identified in prior rounds were used as sensitizing concepts, but we still coded anything related to the larger themes. All authors coded the same two transcripts in this way and then discussed discrepancies to converge on a final codebook. Sharma and Nair then used this codebook to code the remaining three transcripts as well as to recode the original seven transcripts. The figures are illustrations aimed at providing a concise high-level picture of our main findings and the relationships between them. They are based on our findings, but not generated through any rigorous process.

The research team brought several perspectives that should be acknowledged as potential influences in the interpretive process. Faculty Lee is very involved in working with large numbers of undergraduate students and all the remaining team members are undergraduate researchers or were undergraduate researchers when starting this project.

3.3 Limitations

We acknowledge several potential limitations of our study. While the initial recruitment survey was sent to all engineering faculty, the faculty that responded and participated in the study likely were those with a greater amount of interest in recruiting undergraduates or those experiencing greater challenges to recruiting students. However, this may be okay since the focus of this study is to better characterize the barriers that faculty face. We also note that most participants were from the Computational Media (5 out of 12 participants) and Computer Science and Engineering (4 out of 12 participants) departments, though we believe this is reflective of computing-centered faculty. Last, our interviews centered on one institution, so more work needs to be done to validate these findings at different institutions. Nevertheless, based on our understanding of the literature and communities that we are in, we believe these findings will be transferable to most other computing faculty at R1 institutions.

4 MISALIGNED SYSTEMS: THE RESEARCH WORLD VS THE EDUCATIONAL SYSTEM

A significant area in which we identified misalignments was between the educational system that students are immersed in and the research world that research faculty and projects are embedded in (**Figure 1-1**). We found misalignments as early as K-12 with the *preparation students receive and mindset they develop in the school system*, which doesn't equip them for the autonomy required in research or the uncertainty intrinsic to it. Once in college, *student time is highly constrained* by degree related priorities such as coursework, work, or improving their GPA. At the same time, *faculty time is also highly constrained* with graduating students having priority for mentorship time and undergraduate student interaction centered on teaching increasingly large classes. Moreover, there is a *lack of systematized pipelines* for getting into research. Recruiting and applying is therefore ad-hoc and dependent on student networks and courses, both of which are imperfect channels for several reasons.

4.1 Preparation in the school system is misaligned with research

The research world requires students to *"be self independent"* (Sam) and to be able to work in unstructured environments. Several faculty pointed to the class system as giving students a misaligned mindset. As some faculty described,

> *"They're just like, give me stuff to do. That's hard to work with. too much like class as opposed to research." (Tessa)*

> *"if you're used to taking classes and an assignment every week, I can't provide that structure for students [in my research lab]" (Manuel).*

While faculty expressed understanding that this was a skill to be developed, they also accepted students into their research labs based on their ability to work independently.

> *"[Undergraduates have to be] able to do a certain amount of independent work. I mean, this is the hardest part of doing research. And it's a skill you have to develop of course, but at least show that, you know, they have some motivation that they're, they're willing to do things that are a little bit less supervised than, you know, like, work for a class" (Robert).*

Furthermore, this misalignment is exacerbated by undergraduates not being well informed by school systems about the uncertain nature of research.

> *"And they don't really know what research takes. Some of it is just kind of being in a state of not knowing what's going to emerge from it; there's a lot of uncertainty" (Manuel).*

4.2 Student time is highly constrained by degree related priorities

Once students get to college, one of their main priorities is to focus on obtaining their degree. As faculty put it,

> *"[Undergraduates are] still focusing on courses. And also for college students, they have other things to work on too. There's exams; there are other activities." (Jun)*

> *"They're too busy trying to get a get get a 4.0 and get off after school to work. So yeah, it's a special person, I think, who's interested in doing research?" (Manuel)*

Due to this focus on classes, faculty find that undergraduates often do not have the time or energy to conduct research.

> *"They're busy with the classes, I understand. The first thing that they have to do is pass the classes… They don't have time. They just class class class class. And they don't have time to do anything but classes" (Sam).*

> *"I think sometimes with students, it also seems like they think they'll have more spare time than they have. And so then, you know, classes just kind of take over, and then they're not able to make progress" (Lucas).*

Even when undergraduates were able to begin working in research labs, they *"would often get kind of overwhelmed with their course load and sometimes not respond to emails"* (Ava) or simply disappear.

> *"But sometimes they come for like months and months and months. And then finally they disappear. And you know, I've already got excited about and I've already brainstorm how to get them involved in a project, but then, you know, it's not their fault, right? They are taking on five classes or eight classes or whatever" (Manuel).*

This was also reflected in the early filters that many faculty have to see if students have enough interest to put in some minimal time, reasoning that if undergraduates *"didn't have the time to do that [filter task], then they're not going to have time to do research"* (Tessa). They want to know if they *"have enough time and energy even to do this work, even if it's only five hours a week"* (Keith), or it *"is not the right time to get involved"* (Noah).

4.3 Faculty time is highly constrained by advancing research or teaching classes

Meanwhile, faculty time is also highly constrained by other priorities. As Oliver states, *"my time is highly constrained; I deal with lots of students, I have to prep classes, I do other things...I enjoy mentoring students, but I understand that I quickly get flooded."* Or as Aria describes, despite wanting to *"actually get some one on one time with undergrads... just to kind of check in and get to know them a little bit,"*, they find themselves asking, *"how [do I] manage my time?"*

> *"I was a department chair... that just soaked up huge amounts of extra time. Whenever I had spare time, it's like I had to focus on some administrative thing... (Lucas).*

We observed that when working on research, faculty prioritize mentoring graduate students and therefore only have little amounts of time to give to undergraduate students.

> *"I will categorically not give undergrads their own research project, because I'm entering time. But it doesn't work one to one. So like, I always paired them with grad students now" (Oliver)*

> *"I actually like budget how much meeting time might give depending so like undergraduate like 15 minutes, yeah, and master's I give 30 and PhDs get an hour that kind of got it." (Keith)*

> *"There was also a period when I had too many grad PhD students. And so then what time I had for research, I needed to spend on mentoring PhD students" (Lucas).*

Much of faculty's engagement with undergraduate students centers on teaching large classes. One faculty described interaction with undergraduates as teaching-centric in contrast with and in opposition to interaction with graduate students that is research-centric.

> *"We have very large undergraduate class loads, which are sucking up people's time to think about how to use it, not just to teach the classes, but administratively, we have an enormous number of people doing their service. We're trying to make this thing work. And so that directly trades against PhDs. So the university has to decide, do they want more undergraduates, or do they want more PhDs?" (Oliver)*

Another faculty described the extra work of writing recommendation letters that also would result from working with undergraduate students in research.

> *"there is a kind of expectation [to write letters for] undergrads [who] work in the lab, and it's like, great, I'm happy to do that. But, you know, then I get down to late December, and I'm just like, Okay, I got to write all these letters now, which is like, why did I say yes to all these letters?" (Lucas)*

4.4 Lack of systematized pipelines for undergraduate research

The separation of the research world from undergraduate teaching also meant that there were not systematized pipelines for students to get into UREs and a lack of centralized administration for supporting such pipelines. As Ava explained,

> *"it's not centralized or particularly well organized, and it can be kind of overwhelming... It's a lot of me having to do like work to attract and get funding for students, where [my old university] made the barrier to students getting involved with research very low, and there was one centralized place to do it." (Ava)*

This lack of systems for finding and joining labs means that undergraduates *"don't know what the different labs are doing. They don't know what [faculty are] doing. They don't come to see" (Sam).* It also means that there aren't clear channels for landing a position.

> *"For undergrads is not a very good system. I don't like it. The main way to get it currently is by telling classes that they should be going to talk to grad students- to some professor and try to join some lab" (Sam).*

This means that students need to have initiative and motivation to find their way in. Oliver described the students who *"managed to convince me to let them come to lab meetings"* as having *"extreme stubbornness"*. Mentorship started only after the student *"ended up doing something that was getting close to being able to write a paper in our joint lab and so then mentoring became required"*.

The lack of systematized pipelines led faculty to depend on imperfect channels for recruiting undergraduate students, one of which is graduate student networks. As Aria describes, *"I've mostly been just mentoring my PhD students, and they've been kind of doing the most of [undergraduate recruitment]."* Lucas described how *"One student I got involved, I got involved because one of my students was their TA."* However, graduate student networks have their limitations. Sam explains,

> *"I also tell my masters or PhD students to try to actively look for undergrads... They [don't do] so good because they don't interact so much with the undergrads. The best to attract tend to be masters students who used to be undergrads here and they still have friends and those are the ones who tend to attract more undergrads." (Sam)*

A second channel faculty use to recruit is through classes, but this limits recruitment to the classes one is teaching.

> *"I didn't get any undergrad classes to teach. So I'm literally relying on my students actually going out and*

> *finding them for me. I don't have like, any pipeline of undergrads right now at all" (Aria).*
>
> *"Yeah, I would like to reach a broader diversity of skill sets of students. So when I was in the psych department, I got all psych and cog sci majors, which is what I have right now in the lab. But we actually need different perspectives and skills so we can build robots... but I don't teach classes like that yet. So it's harder for me to recruit. Because I don't have a chance to get to know those students." (Tessa)*
>
> *"I'm only recruiting from the course. But also students, they spread the words. For us, I do receive emails from people saying, Okay, I heard about this from my friends who took your course. And we try it sometimes, but nothing serious happened." (Jun)*

One of the biggest benefits of recruiting through classes is that faculty already have a prior relationship and understanding of the student's work. As Manuel describes,

> *"I have a higher percentage of these relationships working when I've known them over the course of a class, showing that they've done good work. And we have a relationship already. Yeah, the ones who come out of the blue, I would say, I think zero percent have worked out." (Manuel)*

However, Oliver described that even this benefit is being eroded by the trend towards larger classes.

> *"[In the past], I knew every student in the class, and I knew what they were doing by the end of the class. Because I had a personal rapport with them, it was more likely that I was going to take them to come be a researcher in my lab. So I now have more than 100 students who are mostly anonymous to me, I've gotten rid of, because of the scale of the class, I've gotten rid of sort of projects where they can actually shine and do something and make everything to be standardized assignments." (Oliver)*

5 MISALIGNED GOALS: ADVANCING RESEARCH VS EXPLORING OR BUILDING CAREERS

Misalignments at the system level manifest themselves in misaligned goals (**Figure 1-2**). Because students lack knowledge of research and are focused on completing their degree and finding a job, their goals often center on *exploring to clarify interests* (in different fields of work or in industry versus academia) or on *building their career* (building skills, adding to their resume, or graduating). Contrastingly, while many faculty express that *supporting students is one of their primary motivations* for mentoring UREs, the time they can provide students is still heavily *dependent on the extent to which these students are able to advance research.* This means that despite the exploratory goal that many students have, many faculty are looking for those students who can *already clearly articulate an interest* in the faculty's area of work or in graduate school and/or *students who already have sufficient skills.*

5.1 Many undergraduates are motivated by exploration or building careers

Faculty described one of the primary undergraduate student goals as centered on exploration. They are *"trying to learn to see if they like the lab or not" (Sam)*, or looking to *"just... kind of soak up experience" (Manuel).* As faculty describe,

> *"Nobody knows when they're an undergrad that they want to do a PhD… Nobody knows what they want to do. A few but like, nobody knows that" (Oliver).*
>
> *"what is it that they really want to do? and sometimes they don't know, right? somebody they just hear, okay, I [found] your lab. you're doing such and such. I'd like to be involved, but they didn't really know what they want to do" (Noah).*
>
> *"They kind of get some experience of what research is like, but then maybe they discover that this particular task or particular lab wasn't for them. It's a lot of, you know, me trying them out, and them trying me out" (Lucas).*

For some students, they're not looking for research experience. Rather, they *"want to learn something or they want to get some new experience" (Noah)* for a resume or future career in industry.

> *"I don't think all undergraduates want research experience… when you start thinking about engineering students, a lot of them just want the skills they need to get the job they want that pays well" (Aria).*
>
> *"Sometimes people were, you know, just desperate for anything" (Ava).*

Ava mentioned that *"I think one time I had a student [trying to join the lab] who wanted an easy A to graduate" (Ava).*

5.2 Faculty want to help students, but their goals still center on the need to advance research

Many faculty described that their primary goal in engaging in UREs was to support undergraduate student learning.

> *"If I just have a point of view of pushing my research... I don't need the undergrads. Sometimes they help; most of the time there are more distraction than a help. The reason mostly why I tend to undergrads is because I think that there are some who are good and if they want to go to a good grad school, they need to do something more than classes." (Sam)*
>
> *"even if [involving undergrads in research] doesn't, you know, lead to some great advance in my own research, at least the students have gotten some experience..." (Robert)*
>
> *"the ideal outcome for me would be that see graduates that are interested in pursuing like graduate degrees or even like industry jobs that are more like research oriented, to have those opportunities and to really think outside like be able to think outside the box... to get to their graduate school of choice. And building those skills to enable them to be competitive" (Isabella).*

However, even for most of these statements, one can see the goal of advancing research as an assumed persistent goal. Additionally, several faculty described the time they put in as making sense to the extent that it could help with *"actually progressing the work" (Ava)*. Manuel said, *"I had a couple experiences where the students took a lot of time and then did nothing"*. Then in reflecting on his statement, he described that as *"sounding jaded and cynical"* and wished he could support students in a way that also worked out for his research.

> *"I would if there were a surefire way to identify great students, and bring them in. I feel like that's part of my mission as a Professor, is to help good students, but I don't. It just seems to hit or miss." (Manuel)*

Keith described being willing to *"still kind of lightly advise"* a project less likely to be published, but that this would *"just reduce how often I meet with them."* Noah described this as also applying to assigning graduate student mentors:

> *"I wouldn't give a grad student the responsibility of working with an unwilling undergrad. I want to make sure that they are serious... because grad students get paid GSR and that's important money and make sure that they don't waste their time" (Noah)*

5.3 Faculty look for clarity of interests and skills in recruitment

The goal of advancing research affected how faculty filtered candidates for UREs. For some faculty, they looked for clarity in the specific research area or project because *"if they're interested in something that is not what we do, then there's no point" (Noah)*:

> *"I would interview a few of them to just kind of get an idea for how interested they were in the project" (Ava)*

> *"Yeah, for me, the filters are really like, do you really want I work in this research area. Are you just looking for any research?" (Tessa)*

Robert described how *"I don't have really specific requirements"*. But even in that statement, he revealed that clarity of interests was an assumed given: *"I guess I would want to know, know, the student was actually motivated and interested in what I was working on"*.

Noah also described looking for clarity in pursuing research careers, someone who is *"strong serious that wants to do grad school who has you know, potential."* For him, UREs also helped with recruitment: *"And what I do is also I use this to actually recruit masters and PhDs. Many of my best PhDs were undergrad students with me."*

Tessa described looking for clarity in the type of work they wanted to do or learning goal, explaining,

> *"Are you passionate about this? Are you just trying to add something to your resume? For the heck of it or because your parents told you that you should? And that's when we asked them, what do you really want to get out of this? Like, what skill are you trying to build? What thing are you trying to learn? If they don't have a concrete answer and they just say, 'I'll do anything,' then we don't invite them into the lab." (Tessa)*

Finally, some faculty were looking for students with *"relevant coursework" (Ava)* or sufficient skills.

> *"So once the interest is, right, once we match interest, and I give them, you know, this test of fire, if you will, so this is gonna, we're gonna look like, if you're not interested in dealing with this math or this object, then there is no reason to, to actually pursue it" (Noah).*

> *"I want to recruit undergrads that have more background... in the skills, because it does take a long time to train students that don't have experience in the skills to acquire those skills" (Isabella)*

> *"I mostly I just want to make sure that there's some degree of interest and then there is a plausible story that they'll be able to handle the work" (Lucas)*

Despite faculty expressing a goal of wanting to support students, their need to advance research in the process led them to look for students who already have clarity of interests or prior skills. As indicated earlier, many students may not be able to provide this since they are looking to explore and build skills.

6 MISALIGNED EXPECTATIONS: REALITY OF RESEARCH VS EXPECTATIONS FOR LEARNING

For students who do begin a research experience, misalignments in systems and goals can lead to misalignments between expectations and reality (**Figure 1-3**). *The nature of work tasks and activities can surprise students* as there can be tedious work required to advance projects (that may not always entail learning) or intimidating work requiring certain skills. Students also face the reality of faculty and graduate students that are *unable to give the supervision and structure of classes* and that also *may not have the training to be effective mentors.*

6.1 The nature of tasks and activities can be tedious or intimidating

One area of misaligned expectations comes from the nature of lab work, particularly the day-to-day tasks which can be either tedious busy work necessary to advance the research or intimidating advanced concepts. Faculty explained,

> *"Three quarters of the challenge in this task is coming up with the training data, which can be a lot of like manual effort. And nobody wants to do the boring... thing of training the label, and then you get to do the 10% of the fun learning" (Lucas)*

> *"the people are so excited to the concept of getting a job — but my work involves dirt. People are shoveling and doing things outside on a farm. And they don't always like it" (Sam)*

Because of this menial, but necessary work, students often *"didn't like tasks"* or *"didn't like the lab or they got too busy. But the main issue is that they tend to disappear. You then never never see them again." (Sam)*

The type of lab work can also be too advanced, consequently intimidating undergraduate students. Aria says that lab environments can be intimidating for less experienced students:

> *"Like, right now, our lab meetings are mostly just the PhD students talking, right? So I feel that they [undergraduates], if there's just one or two undergrads in there, that could be quite intimidating" (Aria).*

Noah mentions that they check to see if undergrads are *"scared or not scared of a lot of mathematics"* because their lab requires advanced mathematics knowledge and *"partly because some research led theoretical, yeah, people got scared away."* Both faculty indicate that students are driven away by fear of the perceived difficulty of lab work.

6.2 Expectations of close mentorship and supervision may not be met

As we already saw in the system-level alignments, students are not prepared for the autonomy required in research. Closely related to that is the expectations students may have of close mentoring or supervision that is not met by many lab environments. As described by faculty,

> *"And so the students who were okay with it tend to thrive but the ones who really feel like they need constant supervision, you know, the lab doesn't have the time to. . . my lab is not set up right now to give that." (Manuel)*

> *"it's good if they can program. they should be self independent. there is not tasks that we are going to be telling them what to do. So they have to figure out the problems" (Sam)*

> *"I really need students to be able to sort of give tasks sort of a higher level of abstraction and kind of have them do some of that breaking down work." (Lucas)*

Faculty acknowledged that it's not just their availability to mentor, but that they are also still growing in their capacity for mentorship.

> *"yeah, I'm not totally. you know, personally, I am interested in growing my capacity as a mentor, and an advisor. And I've always sought out opportunities, you know, the business school or wherever, to learn how to improve things. So, you know, definitely open to figuring out how to prevent something like that in the future." (Ava)*

This was also true for their graduate students, with Oliver saying, *"Not every PhD student is good [at mentorship]."*

> *"I only have one [graduate student] and she doesn't really get along well with undergrads. So I've been avoiding adding them for her sake more" (Keith)*

7 THE CHALLENGE OF GETTING TO AND MAINTAINING STEADY STATE

In the previous sections, we identified three areas of misalignments creating barriers to UREs. This final results section describes the challenge that faculty experience trying to create alignment and achieve steady state (**Figure 1-4**). Faculty describe several areas in which successful UREs depend on *their ability to build and maintain effective team or organizational structures*, e.g., for communication and peer collaboration. Doing this required significant managerial time, and could suck up even more time when done poorly, a problem since many faculty are not trained for this. These structures are also better when there is a critical mass in people and projects, but involving more students further limits faculty time. This work often needs to be *personalized or customized to individuals*, whether to the undergraduate mentee's interests, knowledge, and independence or to the graduate mentor's projects or abilities. This means that there are often *disruptions which mean wasted work or that requires rebuilding structures* all over again.

7.1 Creating alignment requires building team and organizational structures

Faculty described needing to engage in articulation work to build team and organizational structures to mitigate misalignments or described situations in which such structures would have helped. For example, Aria described developing processes and norms that encouraged open communication.

> *"there's the kind of undergrad that kind of disappears on you because they get so overwhelmed. They don't know what to do and then they just never come back. So learning to like, kind of nip that in the bud. Get them to come talk to me sooner rather than get to the point where they're feeling overwhelmed... keeping open lines of communication has been a big thing." (Aria)*

Isabella talked about a need to develop training programs for her students,

> *"stuff that's not taught in any classes... the big picture, like, what are we doing? What are the tools out there? What are the skills, what are the mathematical models behind these tools, what you know, is kind of the big picture of the field?" (Isabella)*

This led her to developing her own training program that *"ended up being more like I gave a summer school. I would meet with them twice a week, they'd do some tutorials, and then discuss among themselves"*. This was, however, too much work. *"So that is not an ideal recruitment for me... there's like a huge infrastructure to kind of train a lot of students... I just don't have the bandwidth for that going forward."*

Lucas described the significant time required to break down projects into smaller tasks that could be delegated,

> *"So you know, take a really big task and like, make it into manageable pieces, but to sort of delegate it, yeah... I just don't have enough time to, like, you know, for every single person" (Lucas)*

Several faculty also described or alluded to the value of community structures to *"integrate [students] into the lab better" (Lucas)*. For Ava, it was a situation when she hired two students thinking that the older student who was more experienced could mentor the younger one who could stay involved longer.

> *"instead, they did not collaborate well at all. And it was a huge overhead to manage both of them" (Ava)*

Oliver described how such an effective community required *"a critical mass of people and projects"* and that he was not taking students until he could build a *"structure that supports them in a way that makes sense"*. He explained,

> *"I think it works best if you join a lab, which is dynamic, and has multiple students that are doing things and you join a project that's already running." (Oliver)*

Achieving such a critical mass, however, would increase the challenge of faculty time,

> *"now my labs bigger, I don't have as much time or energy." (Manuel)*

> *"fixed amount of time available to mentor and you can mentor fewer people more deeply, or you commit to more people more likely" (Oliver)*

7.2 Structures need to be personalized so are ever-changing and require continuous iteration

What we found most interesting about the need to engage in this articulation work is that they not only had to do it once, but it was a continuous process. Faculty described needing to personalize tasks, *"you're matching the work to like their interests as well as their capabilities." (Lucas)* As Robert explained,

> *"Some of my students needed not much in the way of structure and they could just kind of go and we would meet and have advice and so forth. Others, I had to give them more specific tasks. So I think that there's not like one size fits all rule and it just depends on the student how much independence they've developed so far, and you know how much background knowledge they have about things" (Robert)*

Faculty also needed to personalize the management of individual students as well as the training provided to them:

> *"different students require different amounts of different levels of micromanagement" (Robert)*

> *"To get everyone up to speed on a rolling basis as they come in the lab... they're all have different skill sets and I feel like they all need to be up to speed but they all have their different speeds to getting up to speed." (Isabella)*

They also needed to personalize to graduate students too, to consider whether the *"graduate student would get along well with undergrads" (Keith)* and the fit between a particular undergraduate student and a graduate mentor.

> *"usually you have to give them something that they will enjoy to do. And, and something that it benefits the grad student" (Sam)*

The implication of this is that one is continually trying to reach and maintain steady state as students come and go. Because of the short unit of involvement being *"only a quarter" (Tessa)*, work spent can be wasted:

> *"sometimes they come for like months and months and months. And then finally they disappear. And you know, I've already got excited about and I've already brainstorm how to get them involved in a project, but then, you know, it's not their fault, right?" (Manuel)*

For one faculty who worked with many undergraduate students in the past, but then left to work on a startup, this disruption meant that they had to start over in building the critical mass for an effective community,

> *"So also this time lag, like, I hope that I'm gonna, like, it's not that I never want undergrads again... but I left to go do a startup. And then I've been ramping my lab back up... I don't have enough to sort of like, I don't have a lab environment." (Oliver)*

8 DESIGN IMPLICATIONS: OVERCOMING BARRIERS TO MISALIGNMENTS

In this section we briefly illustrate how our framework on URE barriers from the lens of misalignments can be used to examine existing programs as well as to generate ideas for new approaches to increase opportunities for UREs.

8.1 Three approaches to supporting UREs in computing and how they connect to misalignments

Many existing approaches to computing UREs work by addressing misalignments across systems, goals, and expectations. Course-based undergraduate research experiences (CUREs) [32] require an intense amount of work at the start when developing the course structure. However, one automatically gets significant alignment at the systems level by having courses double as contexts for research, and if one is successful, alignment in both goals and expectations also follow as a consequence. Once developed, structures are also relatively stable due to the significant upfront investment (unless the research project changes).

Research Experiences for Undergraduates (REUs) are another approach, often taking place through paid summer internships such as in the ProHealth site [21]. Unlike CUREs which work by linking the educational and research systems, summer REUs circumvent several misalignments altogether since research does not clash with coursework and comes with funding for faculty, staff, and students. By giving students the opportunity to explore research outside of the school year, misalignments in goals and expectations are also less likely if students continue in the Fall. Best practices often relate to creating alignment in student goals for exploration and student expectations for structure. For example, REUs that facilitate collaboration, teach the social impacts of a career in computing, and inform students about graduate schools admissions and life spark greater interest in students in becoming computing faculty [42]. Some tensions still exist though, such as in student expectations for mentorship versus reality of faculty training and time [5].

The Early Research Scholars Program (ERSP) is a non-traditional REU site that has the funding support of REUs as well as integration into courses through a course-supported group-apprentice model and a dual mentorship structure [1, 6]. Their partial integration into courses helps them to create alignment similar to CUREs and their dual mentorship structure helps relieve faculty mentors of some mentorship load to better meet student expectations.

All of these above programs are effective ways to tackle misalignments (CUREs and ESRP for early research experiences and other REUs for deeper involvement), and have been found to improve student's research skills, encourage underrepresented students to

pursue research and academia, and help undergraduates feel a sense of belonging within the research community. But what should one do when one does not have access to funding resources for REUs? Or when the teaching needs of a department don't allow for faculty to swap their teaching for course-based research experiences?

8.2 Lightweight, relational pipelines as systems of action

In discussing the design of ecosystems, the authors of Design Unbound [2] introduce the idea of a *system of action*, 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."* To some extent, the exploratory reading groups we ran that sparked this study began to do just this. Because they were very low time commitment and were designed to be scalable and sustainable, it was easy for faculty to propose themes and for students to participate, overcoming the barriers of constrained student time (**Section 4.2**) and constrained faculty time (**Section 4.3**), and to meet student goals of exploration (**Section 5.1**) without imposing large amounts of time on faculty. Because they supported relationship building in small groups, they provided a way for students to connect with peers working in research labs, to learn about what research entailed, and to reach out to faculty, overcoming the barrier of a lack of research pipeline (**Section 4.4**). This, along with the core focus of the groups on reading research papers, helped to give students a sense of what research is about, overcoming the barrier of lack of preparation (**Section 4.1**) and reducing the need for faculty to do more work filtering on clarity of and a match in interests (**Section 5.3**).

We think an interesting direction for future design is to consider what other ways might one be able to create lightweight and scalable experiences that fit within student and faculty time constraints, but that can create relational ties that grease the wheels a bit in the undergraduate research pipeline. These ties could be between peers, with graduate students or faculty, or even with alumni, e.g., for better visualizing how participating in research can pay off for non-research careers.

8.3 Drawing on implicit and complex crowdsourcing for aligning goals

While the above approach may be effective for many of the system-level misalignments that prevent students from ever participating, they do not address the challenges of misaligned goals and expectations after one has started to participate. For example, students focused on skill-building for their career may only be interested in one part of a particular project (**Section 5.1**) and not in aspects of the work required to advance research and publish (**Section 5.2**).

We see the crowdsourcing literature as an interesting source of inspiration for this challenge. For example, a significant thread of work in implicit crowdsourcing considers how one might align the things that people want to (such as developing habits, playing games, or learning) with other larger objectives such as environmental sensing, folding proteins, or translating the web [14, 25, 45]. It is worth noting that aligning objectives with learning in particular has a significant enough literature to merit its own term, *learnersourcing* [23], and includes literature on aligning skill-building with supporting large experiential projects [24]. Another thread of work in crowdsourcing considers how to break down projects into smaller tasks or roles in workflows or organizational structures [11, 26] that make it possible for individuals with limited experience and time to contribute to advancing complex work. A similar such approach might allow students to work on the parts that interest them while still advancing the project as a whole.

Of course, the ideas of this direction are likely not feasible without the support of digital platforms helping with the coordination of work. Additionally, applying these ideas to advancing state-of-the-art research will be a challenging endeavor. However, one does not need to solve the entire problem at once. Even designing a system that works for a specific type of research or a specific part of research can help make progress on overcoming this area of misalignment.

8.4 Digitally-enhanced organizational or community structures for augmenting mentorship

This discussion on crowdsourcing also naturally leads us to our final direction on digitally-enhanced organizational or community structures. Many new advances in crowdsourcing, particular in complex crowd work, go beyond workflows to considering computationally-enhanced teams or organizations [38, 44]. But beyond their value in aligning goals, similar structures may also be valuable in addressing barriers due to misaligned expectations.

For example, while faculty currently do not have time to provide the mentorship and supervision students expect (**Section 6.2**), they may very well be able to do so with the support of digitally augmented mentorship structures like Codeopticon, a programming mentorship interface that enabled tutors to monitor and support 226 learners in a 30-minute session [19], or through interfaces for peer mentorship and critique [9, 10, 29], or augmented communities of practice [49]. Both Agile Research Studios [49] and Crowd Research [43], two successful efforts to involve large numbers of undergraduate students, involved the development of new community processes and structures that enabled single faculty to support many students at once. These structures could potentially be leveraged in both course-based research experiences (like in Agile Research Studios) or in typical research lab settings (like in Crowd Research). Many of the existing approaches discussed in **Section 8.1** are already making steps towards this by exploring and iterating on novel team, mentorship, and organizational structures.

9 CONCLUSION

In this paper, we sought to develop a rich qualitative description of barriers to UREs from the perspective of computing-related faculty. Our analysis revealed four primary themes centered around the core concept of misalignments. Misalignments were found between the education and research system, between faculty and student goals, and between expectations and reality of research. Overcoming these misalignments required significant and continuous articulation work for building team and organizational structures that had to be maintained with the flux of incoming and outgoing

students. We showed how considering these misalignments generated new directions for scaling UREs that are not limited by the need to request (often limited) resources, such as through designing lightweight, relational pipelines as systems of action; drawing on implicit and complex crowdsourcing for aligning goals; and using digitally-enhanced organizational or community structures to augment mentorship. Our hope is that this work will help researchers in education and social computing to collaborate with one another in generating new solutions aimed at reducing barriers to UREs and scaling opportunities to all students.

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A CHALLENGES THROUGHOUT THE UNDERGRADUATE RESEARCH JOURNEY

We observed challenges across the entire URE journey, from when undergraduates discover and apply to a lab, to when they get through initial filters and persevere through obstacles, to when they find a sustainable rhythm (**Figure 2**). During our first round of analysis (of the initial set of seven faculty), an undergraduate author took faculty quotes—all of which are italicized below—from our initial set of open codes, and wove them together into a narrative of the student journey at different stages, aiming to use a set of quotes representative of what we were seeing. This journey uses faculty quotes to construct an undergraduate's point-of-view of the URE, so as to illustrate how faculty may perceive the average undergraduate applying to research labs. It is taken from faculty quotes and is therefore, a faculty perspective of the undergraduate research experience and not a direct representation of the URE from the undergraduate themself. We present it here, with a few extensions after our second set of interviews, as a synthesis of the challenges undergraduate students face throughout their research journey[3] through the eyes of the faculty.

A.1 Discovering and Applying to Join a Lab

My mind begins drifting as my professor rambles on about a topic I am already fairly familiar with, focusing just enough to note down anything interesting that was said. I start thinking about graduation and realize that I *need to do something more than classes* if I *want to go to a good grad school.* I begin to wonder what I could even do or where to begin to improve my college application or who I would ask for a letter of recommendation when the time comes. Luckily, *at the end of that class, [my professor makes] an announcement saying... "if you like this kind of research, and you think you might want to try it for real, here's how you can apply to my lab.* Similarly, if you are interested in other types of research, keep an eye out for opportunities or ask your professors. I know a colleague who *put up the URL for [their] research lab, which has a page that's called "Getting Involved,"* another who *posted an ad… [on] the Undergraduate Research Network*, and yet another who told me that *one student got involved because one of [their research assistants] was [the student's] TA... The student did a really impressive class project* and their research assistant recommended them that way."

At first, I can't believe my luck! I had no idea my professor was taking in undergraduate researchers, and this seemed like a perfect opportunity. But then I started to get *scared away.* What if I *don't have enough time to dedicate to a research project, and it makes sense that [my] classes take priority over research.* What if I'm not *capable of doing good research, just because it's a hard thing.* What is a lab? I *don't know what the different labs are doing. [I] don't know what [my professor is] doing.* I have never thought to go *to see* what happens in a lab.

However, before I can run away in tears, a student braver than I voiced their concerns to our professor. Relief floods my body as he replied, "*anyone who's interested, I will have come and join.* If

[3]We note that there are italicized quotes that don't relate to our misalignment themes and subthemes because our initial open coding was done before we identified and focused on this core concept.

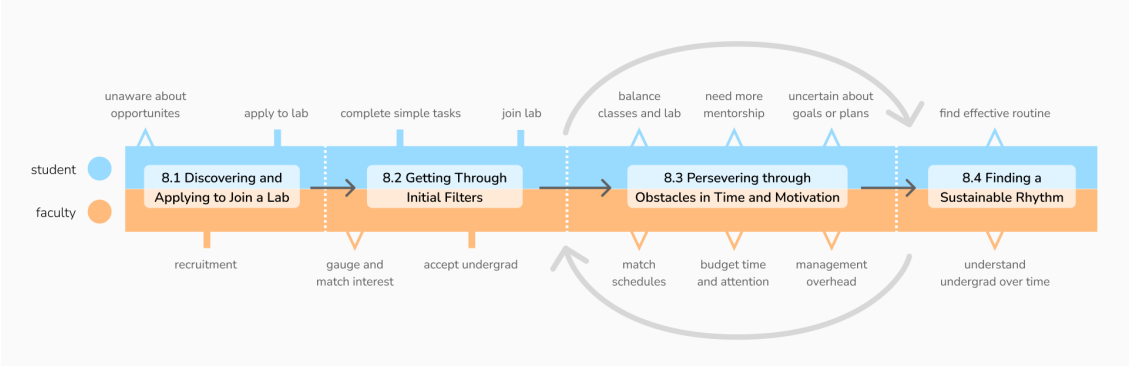

Figure 2: Undergraduate students and faculty go through four main stages in working with each other in UREs. At each stage, there are tasks to be done (solid rectangle markers) and barriers or difficulties that they may encounter (triangle markers) that may cause them to stop working together at any step. Students need to first discover and apply to join the lab (8.1) and pass through initial filters (8.2). Once the student has joined, there is an continuous process of working through obstacles for both the undergraduate and the professor (8.3), including the need to balance their time and priorities, coordinate schedules, persevere through uninteresting work, and converging on common expectations for working with each other. The result could be finding a sustainable rhythm (8.4) or leaving the lab which may potentially leave faculty feeling they've "wasted" their effort.

you're more interested in other labs though, just remember that other professors might require that you have *programming skills*, are *able to do the [lab] tasks*, or are at least *actually motivated and interested in [the lab project]*." Excitedly, I apply to join the lab and wait to hear back.

A.2 Getting Through Initial Filters

I am sent *some sort of simplest task* and am expected to be *able to do it within the week or two.* I hear from a friend that the deadline is extremely lenient though; it's just put there because after that *usually [students] disappear and [professors] never hear from them again,* and that's for those who decide they'll even *show up* to try in the first place. Apparently different labs have different approaches to recruit though; some labs simply interview students to gauge interest by asking, *"What thing are you trying to learn [from this lab]?"*, while others look for *some evidence that [we students]... are actually invested in doing research, or... at least curious... and willing to put in some time.*

Logically, this process to get into the lab makes sense: *Start with a small incremental task that isn't mission critical to the project, that way you can gauge their interest and if they don't complete the task it doesn't hurt the overall project.* This is especially true because it must *be challenging to find that space* in a lab when resources are limited. Plus, based on my own experiences, I'm sure *there is more effort than return on average* for a professor taking in undergrads in their research.

Later that day, I set up camp in the library and work away on the task. I'm glad that my professor presented this opportunity because he's one of my favorite professors, and the material is very interesting! Additionally, the TA told me that *because I had a personal rapport with [him], it was more likely that I was going to [be accepted] to come be a researcher in [his] lab,* especially since he has *more than 100 students who are mostly anonymous to [him].* He's also always been kind in office hours so I want to do my best to stay on his good side, especially if I want to ask him for a letter of recommendation later.

A.3 Persevering through Obstacles in Time and Motivation

After *months and months and months* in the lab, my peers slowly start to *finally disappear* even though my professor *already got excited about them and already brainstorm how to get them involved in a project that they will enjoy to do... [and] benefits the grad student.* He told me that he's been getting frustrated with accepting undergraduate students, but also said, *"I'd be up for trying more if I have a better way of doing mostly time manage."* He had been trying to balance giving attention to all his students by *actually like budget[ing] how much meeting time [he] might give depending; so like undergraduates like 15 minutes, and masters get 30 and PhDs get an hour.*

He was also struggling with matching schedules, since *we have a quarter system… exams are happening every week"* and he *was traveling at some other points.* He knows that other faculty also find it *really hard... to figure out how to mentor [undergraduates]*, especially because *many of them still need training.* Some faculty are able to make it work by *assigning [undergraduates] to other grad students*, but my professor *only [has] one and [her grad student] doesn't really get along well with undergrads* so that's not really an option. Plus, *there's a management overhead involved in breaking things down for each person* in the lab, which professors are usually in charge of regardless.

At the end of the day, we both agree that *it's not [the undergraduate's] fault* though. I'm also struggling to balance classes and the lab, and am not sure if I should stay. I'm not even sure if I am going to grad school, and an internship would be just as helpful, if not more. Plus, by being put to *help on a task for the grad students*,

I wouldn't even be working with the lab professor as much as I thought, which defeats the purpose of trying to get close to a faculty member. Even when I am able to work with him, he isn't able to *provide that [classroom] structure for students,* making it difficult for me to understand my tasks. Most of all though, the lab is *a huge manual effort. And nobody wants to do the boring... the boring thing* of completing the mundane tasks. Lastly, it feels like we are expendable because I know that my professor doesn't actually *need the undergrads.*

A.4 Finding a Sustainable Rhythm

As I consider dropping the lab, however, my professor encourages me *to come talk to [him] sooner rather than get to the point where [I'm] feeling overwhelmed*, and *keeping open lines of communication [with him] has been a big thing* in keeping me in the lab. He assigns me a *project that's already running*, with a task that I *enjoy to do and... benefits the grad student.*

As I continue working with them, I also realize that it was actually helping me with my *senior capstone project.* I decide that the lab was more helpful than I initially thought so I become *more predictable* and *tend to come and sit and learn.* I learn to *figure out the problems* and *be self independent.* I get used to the time commitment and am *able to find some free time to interact* with the lab material. Nevertheless, I do believe that *it's usually not worth the effort to work with undergraduates [for faculty], unless [they] get really lucky.*