

Mentorship and Legitimate Peripheral Participation in the Research Laboratory

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Abstract—This research-to-practice paper investigates how undergraduates organically transition into researchers through the lens of Legitimate Peripheral Participation. Legitimate Peripheral Participation is a contextual learning phenomenon through which new members become core members of a community. These peripheral members begin with the execution of peripheral low-risk and simple activities, gradually accruing knowledge and experience as they take on more complex and essential activities. They gain legitimacy and access to more complex involvement through interaction with, and mentorship by, senior members of the community.

Our research examines how seven undergraduate students, who are involved with a research lab, transition from peripheral roles to core membership through observation and peripheral engagement, skill development, community integration, increasing responsibility, and collaborative projects. These undergraduates interact with and are mentored by both graduate students and faculty members in an organic fashion, with no assigned mentorship roles existing between the undergraduate students and graduate students or faculty. The focus of our research is not on how one recruits undergraduates to work in a research lab, but on how the identity of an undergraduate as a researcher, both in their own mind and in those of their coworkers, is nurtured and developed.

Through the process of surveys and interviews we extract the core elements of the undergraduates' experience and explore factors that might contribute to or hinder their transition into being more active researchers. The degree of involvement and identification as a researcher varied significantly between the undergraduate students. The key elements we discover at social engagement, physical presence, and near-peer interaction.

Index Terms—Legitimate Peripheral Participation, Mentoring

I. INTRODUCTION

Our research is based on the proposition that involvement in a community organically result in deeper ties to that community, a stronger sense of competence and self-identity within that community, and a stronger skill set in that community. The core concept behind our research is Lave and Wenger's [1] concept of Legitimate Peripheral Participation. We explore the implications and mechanisms of action within the context of undergraduate employees and their transition into undergraduate researchers. Exploring the experiences and

impressions of a selection of such undergraduates, we can gain both an understanding of, and the beginnings of a road map for, the transition of students into researchers.

Our research examines the experience of seven undergraduates and the degree to which they transition from a standard hourly worker to involved researchers. These undergraduates undergo a contextual learning phenomenon through which they evolve from new members to core members of the community. They start out as hourly workers with a range of tasks working in a large research laboratory. We examine how these undergraduate students transition from peripheral roles to core membership through observation and peripheral engagement, skill development, community integration, increasing responsibility, and collaborative projects. They gain legitimacy and access to more complex involvement through interaction with, and mentorship by, senior members of the research lab community. Mentorship occurs in an organic fashion, with no assigned mentorship roles existing between the undergraduate students and graduate students or faculty.

The focus of our research is not on how one recruits undergraduates to work in a research lab, but on how the identity of an undergraduate as a researcher, both in their own mind and in those of their coworkers, is nurtured and developed.

Through the process of surveys and interviews we extract the core elements of the undergraduates' experience and explore factors that might contribute to or hinder their transition into being more active researchers. The degree of involvement and identification as a researcher varied significantly between the undergraduate students.

Viewing our results through the lens of Legitimate Peripheral Participation contextualizes the developing identity of the undergraduate researcher into the broader arena of apprenticeship in communities of practice. Our work provides both a basis for future, larger scale studies and provides guidelines for increasing involvement of undergraduates in academic research. We examine both the experiences of undergraduates who successfully transitioned to a core role as researchers and those who did not make this transition, remaining on the periphery of the research lab community. By exploring both successes and failures we better understand the factors

that may influence the development of an undergraduate's self-identity.

II. BACKGROUND

Lave and Wenger's [1] theory of Legitimate Peripheral Participation emphasizes the importance of social context and participation in social communities as the key mechanisms for learning and self-identity as a member of a community of practice. Newcomers start at the periphery of a community, engaging in simpler, less critical tasks and over time they gain more experience and knowledge, moving towards full participation. Experienced members of the community confer legitimacy on these newcomers through recognition and mentorship.

There are four implications of Legitimate Peripheral Participation for the research community that we want to discuss. First, becoming a researcher is social and contextual and can not be easily separated from the community in which it occurs. In our research, we examine undergraduate students who have the opportunity to become involved in the community, but who are primarily given organically occurring opportunities to interact with the community rather than structured or formal invitations to participate. Second, access and inclusion is crucial. Opportunities and support must be provided to members or they will not be able to move towards full participation. In our research, support and opportunities occur organically through social interaction and the building of relationships, rather than being part of an organized plan of study. Third, mentorship plays a critical role in facilitating the participation of newcomers and their transition to full members. In our research, mentorship as it occurs comes purely from the initiative of the graduate students, rather than being mandated or coordinated by a faculty member. Finally, the community of practice that is a research laboratory is a dynamic and evolving place where new members join and grow into full members of the community.

III. RELATED WORK

There is a not inconsiderable body of work discussing how to increase student participation in undergraduate research and how to structure these programs, often focusing on active, formal steps to increase engagement. Wayment and Dickson [2] discuss methods for increasing involvement in undergraduate research programs. Shanahan et al. [3] provide an excellent analysis of "lessons learned" to improve mentorship by faculty in undergraduate research. The value of structure in these mentorship programs is detailed by Wilson et al [4], and Vandermaas-Peeler [5] explores how undergraduate mentorship by faculty leads to entry into the larger community of practice. John and Creighton [6] investigate how Legitimate Peripheral Participation occurs in a structured undergraduate research program. Packard et al [7] present their finding on how undergraduate peers negotiate their mentoring roles in a research lab, using the lens of Legitimate Peripheral Participation to explore their roles in a community of practice.

In our research, we wish to explore how legitimate participation occurs organically, without any imposed mentoring structure or expectations, in a research setting that includes graduate students, undergraduate students, and faculty. From these observations we seek to find what factors led to successful integration into the community of practice and what factors led to failure.

IV. METHODOLOGY

The research laboratory in which this study takes place is focused on human-computer interaction [8] and the role of technology in education and learning [9] at a large Tier 1 university in the United States. These focuses result in a wide variety of roles for undergraduate employees. The undergraduates are primarily employed as part of several ongoing research projects that use undergraduate students to provide in-school mentorship and instruction to elementary and high school students [10] through both in-person and telepresence modalities. Components used in the instruction of elementary school students are fabricated by undergraduate employees.

The laboratory space is divided into three connected areas separated by doorways. The largest space is desk space for the professor leading the lab, the graduate students, and some undergraduate students and is referred to as the main workspace. The smallest space is an area solely occupied by undergraduates, who perform fabrication work to create components for ongoing research projects and telepresence mentoring work with research subjects as part of other research projects and is referred to as the fabrication space. The third area is a mixed use space where materials and tools are stored, studies are performed, undergraduates provide telepresence mentoring to research subjects. This third space is also occasionally used by graduate students for meetings or to perform other work on an ad hoc basis and is referred to as the mixed-use space.

The subjects in the study had access to a variety of starting positions in the research lab. The most common is a role as a student STEM instructor for research projects involving elementary or high school students. This position has very low involvement in the research community and equally low involvement with the social structures of the lab. The elementary school positions perform their work outside the physical confines of the lab space, while the high school positions performed their work in the mixed-use space.

A second starting position was in fabricating parts. This position had very low involvement in the research community but provided more opportunities to interact socially with other students, especially undergraduate students.

A third starting position was in supporting software development for the elementary school-associated research project. This position offered low involvement in the research community but plentiful opportunities for social engagement when colocated, and took place both in the main workspace and through remote work.

Undergraduate Gender

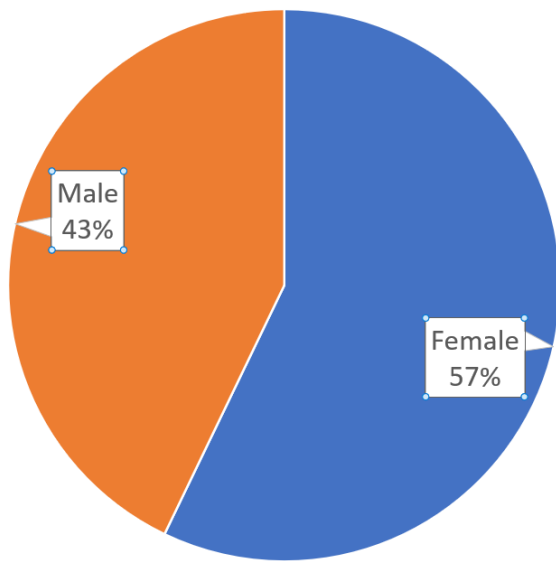


Fig. 1. Subject Gender

During the time period examined, there were six graduate students who were present for the entire time period. Four of the graduate students are Computer Science PhD students, one is a Visualization PhD student, and one is an Engineering master's student. Additionally, an Education post-doctoral person was present for a short period of time. The lab was run by a professor with a PhD in Computer Science. A second professor associated with the lab, also in Computer Science, worked with some of the students.

The graduate students were allowed to invite any undergraduate student or fellow graduate student to help them with their research, but were expected to provide any instruction or guidance such an assistant would need to perform their requested tasks.

A. Undergraduates

All of the undergraduate students were from the United States. None of the undergraduates knew any of the graduate students or the professor running the lab before their involvement with the lab, nor had they had any previous experience participating in research projects as a researcher. Two had past experience with the associated professor, having taken a course with that professor.

The subjects were nearly evenly split between genders (See Figure 1) and the majority were juniors (See Figure 2). All subjects have a technical STEM major, with six in various types of engineering and one in an engineering-adjacent field.

B. The First Three Months

The subjects were surveyed about their initial feelings and impressions during their time in the first three months of

Year in School

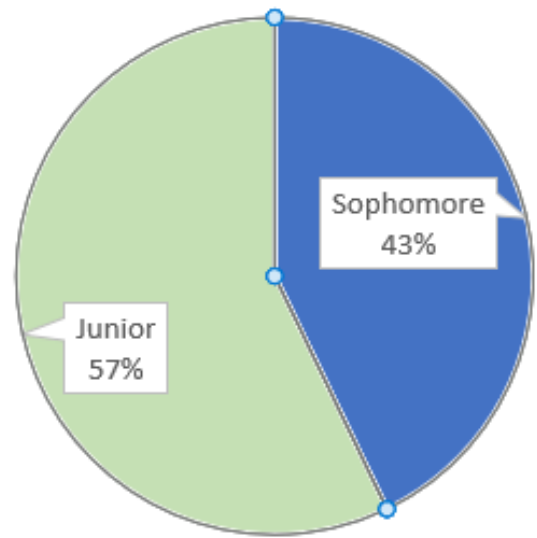


Fig. 2. Subject Year in School

their employment in the lab. This was used to establish a baseline for their initial experience, while still allowing them an adjustment period to get over any initial nervousness about being at a new job or meeting new people.

C. Data Collection

All undergraduate employees of the research lab who had any sustained contact with the graduate students were considered for this study. Seven of these potential subjects chose to take part in the study. The subjects were contacted by email and invited to take part in the study. Subjects were reimbursed \$20 for their participation in the study.

The subjects were asked four sets of questions. The first set of questions covered their experiences and impressions over their first three months of involvement with the lab. These questions covered their initial job responsibilities and work hours, and then used a Likert scale from 1 to 5 to record their comfort level and enjoyment interacting with graduate students, whether they felt comfortable joining or initiating conversations, whether graduate students or professors in the lab were more approachable, whether undergraduates or graduate students were more approachable, and whether the subjects perceived the graduate students as mentors.

The second set of questions covered their current experience and impressions, using the same questions as the first set, but also adding in questions asking them to explain any instances, if any, where they received non-work-related mentorship. This was used to establish if and how the perceptions of the subjects changed over time.

The third set of questions was aimed at investigating the sense of community, derived from the Sense of Community

Index work of McMillan and Chavis [11]. These questions explore knowledge of what work is being done in the lab, comfort level in the lab, a sense of opportunities available, trust in coworkers, and a sense of being seen and known. A total score, summing the responses, is used to get a picture of the subject's overall sense of community.

The fourth set of questions regarded their scientific possible selves, based on Beier et al. [12]. These questions are broken up into three groups and use a Likert scale from 1 to 5. The first group of six questions, the Hoped For Self, records the subject's aspirations for themselves as a researcher: whether they think they will be a good researcher. The second group of seven questions, the Expected Self, records the subject's expectations for their own performance and accomplishment as a researcher. The third and final group of six questions, the Feared Self, records the subject's concerns and doubts that they will not succeed in realizing themselves as a researcher.

For each subset of questions about scientific possible selves, the scores are summed to give a gestalt picture. For the Hoped for Self and the Expected Self, scores closer to the maximum (30 and 35, respectively) indicate positive feelings about themselves as researchers and stronger identification of themselves as researchers. For the Feared Self, a lower score (6 minimum, 30 maximum) indicates positive feelings about themselves as researchers and stronger identification of themselves as researchers.

Followup interviews were conducted to expand on their answers given in the surveys and to provide the subjects a chance to explain their answers in their own words.

V. RESULTS

There are several different paths that the undergraduate subjects took. Some of the undergraduates became highly involved in the social fabric and research of the lab, while others did not. Many chose interaction with graduate students as a primary route to research, while others chose interaction with a professor. Not every subject was interested in research, and even those who came to identify as researchers expressed no desire to pursue a career in research after graduation. There is no single unifying factor that controlled the outcome of an undergraduate researcher, but examining each subject individually gives us a sense of what guided each subject's trajectory.

A. Subject 1

Subject 1 was originally hired for an elementary school position. They then sought further employment "because I needed a job" at a summer position. They scored their initial social interactions with the graduate students in this time period as low but expressed high levels of comfort and enjoyment in what interactions they did have. They were uncomfortable initiating social conversations or joining in on-going social conversations between the graduate students. This subject strongly agreed that the graduate students were more approachable than the professors in the lab, but felt that the undergraduates were more approachable than the graduate

students. The subject strongly viewed the graduate students as mentors.

The subject began to be assigned more complex tasks as part of their employment, which did not lead to a deeper involvement in research, but moved their workplace into the main workspace and resulted in longer work hours in a shared workspace (20+ per week), as well as having their own dedicated workspace. The subject began to get more involved in the social fabric of the research lab. This occurred through increased exposure ("I'd been going to the lab. You all had decent vibes and you all were more approachable.") and through active invitations by the graduate students ("I got looped into a conversation one day.")

The subject became more interested in participating in performing research and approached a Computer Science PhD student for guidance on how to approach other researchers to increase their involvement. The subject then used this feedback to approach different Computer Science PhD students and became involved in assisting with data analysis. Once the subject became known as interested and demonstrated competence, other graduate students that they had formed social connections with invited them to participate in their research as well.

The subject now scores their social interaction with graduate students as very high and expresses a very high degree of comfort in participating in or initiating social interactions. They scored their sense of community as a 70 out of 70. The subject expressed extremely high interest and enjoyment in doing research ("I have enjoyed doing it. I have enjoyed learning about other aspects and what I can do and reading research papers.") as well as extremely high confidence in their abilities. Additionally the subject has had their own research paper published as a conference under the mentorship of the graduate students.

Despite this high enjoyment the subject has expressed that they have never wanted to be a researcher or attend graduate school, and this remains their stance. They view their research experience as a way to build their resume and differentiate themselves in the job market.

B. Subject 2

Subject 2 was originally hired as an elementary school position. They interacted with one of the professors at a work-related social function and a mentoring relationship with that professor emerged. They had little professional interaction or with the graduate students in the lab. They felt comfortable and enjoyed interacting with the graduate students and felt comfortable initiating both work-related and social conversations, as well as joining in on-going social conversations between the graduate students. This subject felt that the graduate students were equally approachable as the professors in the lab, but felt that the undergraduates were much more approachable than the graduate students. The subject strongly viewed the graduate students as mentors.

They transitioned to work in the main workspace that contains the graduate students to work but was not given a

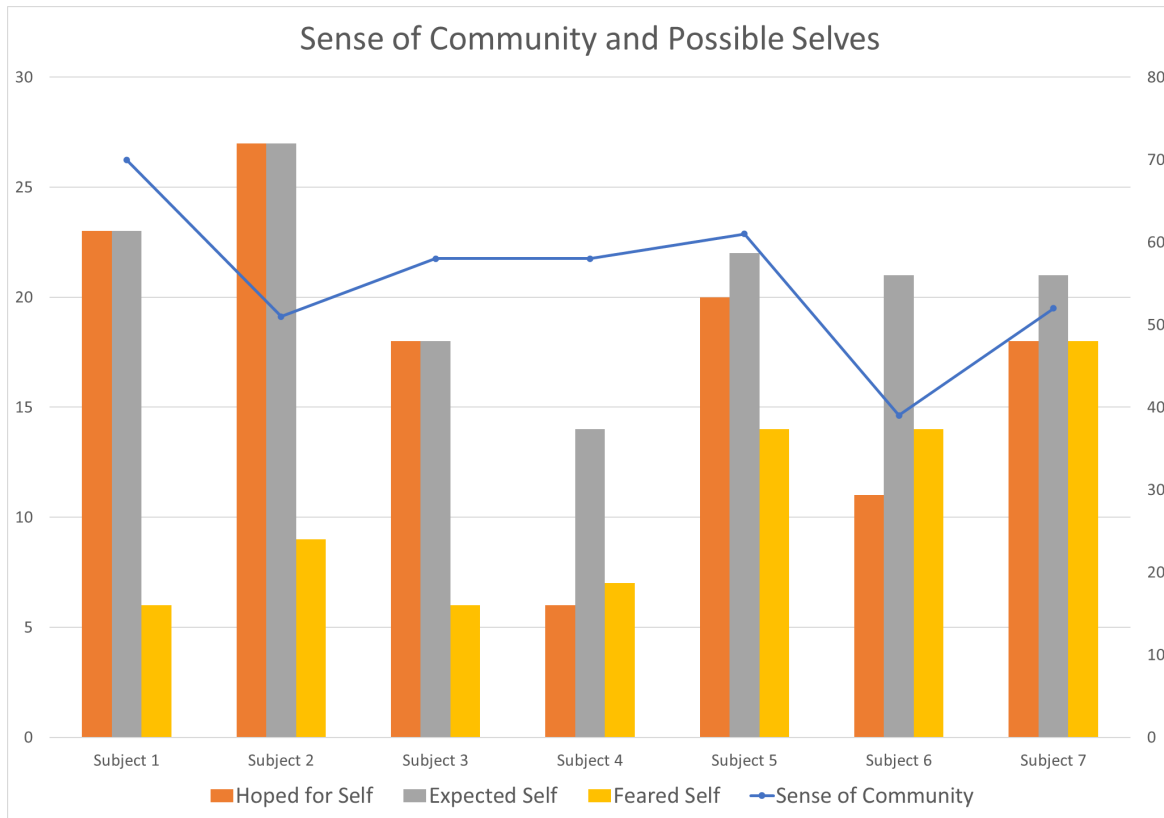


Fig. 3. Sense of Community (right axis) and Scientific Possible Selves (left axis)

personal space. They initially worked about 10 hours a week in the main workspace. However, this time in the main workspace gradually diminished. The student worked directly with one of the professors but had increasingly diminished social contact with the graduate students. This resulted in decreased comfort interacting with the graduate students, specifically in requesting assistance. This lack of social interaction resulted in a below average sense of community (51/70). Despite this, the subject continued to view the graduate students as mentors and maintained important connections to this mentorship ("[graduate student] helped me a lot with my research.") The subject expresses high confidence in their research abilities. Additionally, the subject published their own research paper under the mentorship of one of the professors.

C. Subject 3

Subject 3 originally worked in the fabrication space but was not given their own workspace. They initially worked about 10 hours a week. They had daily professional interaction with the graduate students and an equal amount of social interaction with the graduate students in the lab. They felt comfortable and enjoyed interacting with the graduate students and felt comfortable initiating both work-related conversations and social conversations, but much less comfortable joining in on-going social conversations between the graduate students. This subject strongly agreed that the graduate students were more approachable than the professors in the lab, but felt that the undergraduates were more approachable than the graduate

students. The subject did not view the graduate students as mentors.

The subject has been given additional tasks on research projects by one of the professors. They offered to assist with other projects and became involved with the research paper efforts of other undergraduates, and have been more comfortable interacting and joining in with social conversations with graduate students. They have an above average sense of community (58/70) and high confidence, but expressed ambivalence about the graduate students as mentor figures. The subject does not have any research publications, but has expressed interest in assisting in writing one and has spoken to both undergraduate and graduate students in the lab about assisting in their papers.

D. Subject 4

Subject 4 was originally hired for an elementary school position. They then moved to a position coding video data. They were given their own desk in the main workspace that contains the graduate students to work. They initially worked about 10 hours a week. They had weekly professional interaction with the graduate students but very little social interaction with the graduate students in the lab. They felt very uncomfortable and did not enjoy interacting with the graduate students and felt very uncomfortable initiating work-related conversations, social conversations, or joining in on-going social conversations between the graduate students. This subject felt that the graduate students were no more approachable than

the professors in the lab, nor were the undergraduates any more approachable than the graduate students. The subject did not view the graduate students as mentors.

As the subject spent more time in the main workspace they became more comfortable interacting with the graduate students, eventually becoming very comfortable interacting with the graduate students and viewing them as mentor figures. They asked for both academic ("When I was applying for entry to a major I wasn't sure of what I wanted to do and asked [graduate student] for guidance.") and personal advice. The subject was actively involved in co-authoring a paper with a graduate student.

Despite an above average sense of community (58/70) and some involvement in research activities, the subject expressed a strong disinterest in pursuing a career in research. The subject expressed some interest in involvement in writing a research paper, but solely as a resume builder.

E. Subject 5

Subject 5 who was originally hired for an elementary school position. They were not given any particular space to work and spent a majority of their time working remotely. They initially worked about 10 hours a week. They had weekly professional interaction with the graduate students as well as social interaction with the graduate students in the lab. They felt comfortable and enjoyed interacting with the graduate students and felt comfortable initiating both work-related conversations and social conversations, and did not feel comfortable joining in on-going social conversations between the graduate students. This subject strongly agreed that the graduate students were more approachable than the professors in the lab, but felt that the undergraduates were more approachable than the graduate students. The subject strongly viewed the graduate students as mentors.

The subject became involved in data analysis and content creation for one of the ongoing research projects and was given their own desk in the main workspace. During this time they had decreased interactions with the graduate students, and a corresponding decrease in their comfort level initiating or joining social conversations with graduate students. Despite this, the subject expressed a high sense of community (61/70). The subject expressed a sense of introversion and the difficulty of getting involved as an introvert. ("I feel like unless you're really persistent about getting involved in research papers it can be a little intimidating." "I'm talking to [graduate student] because of [undergraduate student]: she's really outgoing.") They have worked with an undergraduate on their research paper as a co-author and plan to work with a graduate student soon. They have expressed an interest in research ("I like the whole process. It's fun and I like it a lot.") as well as a desire to get more involved in writing a research paper. Despite this enjoyment, they have no plans or interest in graduate school or a career in research, but did at one time ask a graduate student for advice on master's programs.

F. Subject 6

Subject 6 was originally hired as a software developer and worked in the main workspace but was not given any particular space to work. They initially worked about 15 hours a week. They had weekly professional interaction with the graduate students but fewer social interaction with the graduate students in the lab. They felt comfortable but did express neutrality about enjoying interacting with the graduate students. They felt comfortable initiating both work-related conversations and social conversations, and did not feel comfortable joining in on-going social conversations between the graduate students. This subject agreed that the graduate students were more approachable than the professors in the lab, but felt that the undergraduates were more approachable than the graduate students. The subject did not view the graduate students as mentors.

The subject spent a decreasing amount of time in the lab space, eventually only working 2-3 hours per week in the main workspace. This corresponded with a significant decrease in comfort initiating or joining conversations with graduate students. However, the subject did develop a closer relationship with one of the professors. The subject, while expressing an interest in getting involved in a research paper, has not achieved any involvement in any papers. The subject is not interested in a career in research or graduate school, viewing their involvement in research as a resume builder. ("I had to find some place somehow that could stand good for a resume.") The subject ended with a low sense of community (39/70) as well as limited confidence in their research skills.

G. Subject 7

Subject 7 was originally worked in the main workspace but was not given any particular space to work. They initially worked only a couple of hours a week. They had almost never had professional or social interaction with the graduate students. They expressed neutrality about being comfortable with or enjoying interacting with the graduate students. They felt comfortable initiating both work-related conversations and social conversations or joining in on-going social conversations between the graduate students. This subject felt that the graduate students were no more approachable than the professors in the lab, nor were the undergraduates any more approachable than the graduate students. The subject did not view the graduate students as mentors.

The subject maintained this low level of involvement in the lab. They did not become involved in any publications, nor did their impressions change substantially. Their sense of community was below average (52/70) and they did not express confidence in themselves as a researcher.

VI. DISCUSSION

There is no single unifying factor that impacted every subject, but there are certain trends that are worth noting. While none of the subjects expressed a strong desire to become researchers as their future career, and many expressed

a complete lack of interest, it is worth noting that many still chose to **do** research.

One factor that showed a strong degree of influence was social connections. Social connections appear to be most easily established with those who are closer to peers. Subject 5 who expressed issues with introversion, found their route to greater involvement through a fellow undergraduate. Most of the subjects expressed that the graduate students were more approachable than the professors, and the majority of subjects found their mentorship solely through graduate students.

These social connections were most commonly established through spending time in close proximity and establishing a sense of community. Subjects 6 and 7, who spent very little time colocated with the graduate students, were the least successful at transitioning to researchers. Three of those who have build the strongest sense of community, Subjects 1, 3, and 5, have either authored or co-authored publications, with Subject 4 beginning a co-authorship.

This social connection both opened the door to taking on intermediate tasks, mostly data analysis, where the subjects could establish their competence and become establish legitimacy as researchers.

Even more importantly, these social connections establish the activity of research as an activity that is desirable to do. It is noteworthy that, although there is no expression of a desire to become career researchers, most subjects expressed an enjoyment of and a desire to take part in research and the generation of publications.

Access and inclusion are also highlighted by the experiences of the subjects. Those who have opportunities, both through physical presence in the same physical space or through making social connections as Subject 2 did, were those who succeeded most as researchers.

VII. CONCLUSION

There are several critical takeaways from the experience of the subjects. One of the most critical is the accessibility of graduate students. The subjects found them more approachable, and typically relied on them as mentors and as a gateway to involvement in research. Likewise, undergraduates who were successful in performing research and had gained legitimacy in the community of researchers were viewed as potential mentors and experts who could provide entree into the community. This emphasizes the dynamic nature of the research community.

The second critical lesson is the importance of a strong sense of community. The involvement of undergraduates in the social interactions of the graduate students is of key importance in attracting them to doing research. It is important to have proactive inclusion, especially of shy or introverted students is highlighted by the experiences of Subject 5. A lack of inclusion limits access to opportunities.

A third lesson is the importance of mentorship. Those who succeeded in publishing papers both viewed graduate students as mentors, and received mentorship from those graduate students. Empowering graduate students, who are themselves

naturally mentored by their advisors, to act as mentors to undergraduate students can multiply the effects of that top level mentorship.

VIII. LIMITATIONS

A primary limitations of this work is the cultural environment in which it takes place. The university the lab is located in and the students all embody an American culture. Students from other cultural backgrounds may have different levels of comfort or motivation in interacting with and asking for opportunities from authority figures. Additionally, the students attending a smaller university, or one less focused on research, may also behave differently.

IX. FUTURE WORK

Our findings here show a snapshot in time. In our future work we would like to track the involvement of undergraduate researchers month by month, tracking their social engagement, changes in responsibilities and tasks in the research lab, and involve the graduate students in gathering their impressions and evaluations of the involved undergraduates.

We would like to compare the experiences of labs with "open office concept" floor plans to more traditional university labs where graduate students are confined to separate offices and may be less organically accessible. We hope to use this data to determine if lab layout has an impact in the social factors that we found contributed to success for undergraduate researchers.

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