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Research Article

Agency Building with Early Research Exposure: A Study of an Undergraduate Science Education Exposure Program

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Abstract
Undergraduate research exposure provides students with opportunities to positively perceive their association with their scientific discipline through agentic experiences, and thereby fostering their disciplinary identity building. In the present study, we explore students' experiences of participating in an undergraduate level research exposure camp in Chemistry discipline. The camp is organized under a national level nurture initiative for undergraduate science and engineering students in India. It is a two-week long residential camp in which students are engaged in lectures on theoretical topics in chemistry, problem solving sessions, long laboratory exercises, abstract writing session, and students' seminars. The camp also serves as a first step to select a small cohort of students based on their performance in the different activities during the camp for extended research projects opportunities. We apply the critical science agency framework to examine students' experiences during the camp, and how understand how students connect their prior experiences and future career related choices with their camp experiences. The qualitative analysis describes students' accounts of the emergence of agentic personalities at the entry, during, and beyond the camp. We noted instances in which students' decisions and subsequent actions of applying to and attending the camp surfaced, and through students' narration interpreted how some of these were markers of critical science agency. Based on authors' understanding, this is the first, and one of the few studies conducted using critical science agency framework with science undergraduate students about their early research experiences. The study provides insights about potential programmatic features for similar undergraduate research camps in India as well as on a global platform.

Keywords: Chemistry Education, Critical Science Agency, Science Identity, Undergraduate Research Experience

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1. INTRODUCTION

In many studies exploring early science research exposure scenarios, research experiences at the undergraduate level have been reported to play a significant role in increasing students' interest and motivation in pursuing science based higher-level careers. These research experiences are described as helpful in clarifying or confirming students' career choice (Lopatto, 2007; Seymour et al., 2004). Studies have also reported an increase in students' conceptual knowledge and improvement in their nature of science views with research exposure (Ryder et al., 1999; Krochalk & Hope, 1995). In STEM-identity domain, an exposure to undergraduate research is described as something that instills more self-confidence in students perceived via an enhancement in their ability to carry out research activities, participate in the culture of research by developing critical thinking, expressing their ideas, and communicating results, and becoming a part of a science learning community (Bauer & Bennett, 2003; Seymour et al., 2004). However, it is also advised that the program structure should enable students to do something beyond mimicking an established lab experiment and orient the students to the realistic goals of performing research activities (Linn et al., 2015). Given such opportunities, undergraduate research experiences have positive gains for all

students, and are particularly effective in increasing the interest and recruitment of underrepresented groups such as women and students of color in higher-level science education and careers (Estrada, Hernandez, & Schultz, 2018; Hurtado et al., 2009), and therefore, are encouraged as a strategic structural element in undergraduate level education worldwide.

Despite such well-documented gains associated with undergraduate research experiences, research studies in India have relatively fewer quantitative, qualitative as well as anecdotal accounts of how research experiences lead to specific gains, increase positive attitudes or interest in higher level science careers in Indian students (Sen & Ladage, 2023). Many established science research institutions in India such as Jawaharlal Nehru Centre for Advanced Scientific Research, Indian Institutes of Technology, Indian National Academies, Indian Institute of Science, Saha Institute of Nuclear Physics, Tata Institute of Fundamental Research, Indian Institutes of Science Education and Research have been providing undergraduate research opportunities, particularly to first and second year undergraduate students through institutional/national programs regularly for nearly two decades. Though successful, the impact of these programs is understood in limited terms as the reporting primarily takes place in the quantitative form such as - students' influx, number of students trained, projects completed, number of publications etc. More details on how undergraduate research exposure opportunities are impacting undergraduate students' life worlds is therefore worthwhile in this context.

Effectiveness of undergraduate research programs is often attributed to their structural/programmatic features alone, but it is important to understand that students interacting with these structures might have varied interests and identities, so the nature of interactions with these features might be of a varied nature. In published literature, undergraduate research programs are narrated as specifically designed experiences such that students can devote a considerable amount of time to accomplish the pre-designed research tasks. Under close mentoring, students invest deeply in the activity and discuss related science as professionals leading to a deeper learning experience and increased interest. The programs facilitate intense student-student and student-mentor interactions on specific research problems/areas. As a result, students learn subject specific skills and concepts from each other and senior mentors in a more engaged manner (Kuh, 2008). A deepened look at students' interactions with many of the above mentioned structural/programmatic features (time, nature of activity, meeting structure, and training) will provide us with more intricacies about students' life-worlds.

It follows then that some standard academic impact indicators e.g. students' retention and performance in a discipline may not capture the quality and extent of their learning completely. Carol Schneider echoes the true spirit of education when she writes that "[T]the college degree is meaningful, after all, only when it represents forms of learning that are both valued by society and empowering to the individual" (Schneider, 2008). A focus on academic indicators of learning alone prevents a fuller understanding of how students engage with a subject at a personal level. Consequently, the explanatory accounts of student retention in science do not fully grasp the finer aspects of student engagement in science. In many undergraduate programs, students may perform well academically by just gaming the exam pattern, but might be disinterested in any other kind of transactions with science beyond the exams. In contrast, motivated students performing just okay in an exam may develop keen interest in venturing in more avenues of scientific interactions in their real worlds and with associated communities. So, widening our investigations to observe the impact of interactions with structural/programmatic features on aspects beyond retention and academic grade performances are important, and also hold a promise to develop a greater understanding about the success of the program itself.

Hunter, Laursen and Seymour (Hunter et al., 2007) have modeled the learning experiences in undergraduate research using social constructivist theories of learning. According to them, students learn the content and skills of science working in hands-on manner on research problems in close contact with each other and faculty mentors. This 'situated learning' on problems which are designed keeping students' cognitive levels in mind further creates the 'zone of proximal development' leading to their educational, personal and professional gains. During the undergraduate research exposure, students come across semi-organized research laboratory set-ups, experiments, and knowledge bodies. They are exposed to people as mentors, colleagues, research collaborators etc. While making sense of all of it, students need to work their way to achieve some research goals. This journey could be unique to every participant as it is shaped by their decision-making at different junctures of their research experience. A focus on explanations of how students with their distinct identities, values and goals interact with the structural/programmatic features

of undergraduate research programs is therefore useful to understand how the structures can be reviewed to yield positive learning and program outcomes.

With these arguments, we set out studies to develop an account of student engagement in science during an undergraduate chemistry research program using the theoretical framework of 'critical science agency' (Basu & Barton, 2009a; Basu et al., 2009b). The capacity of students to act in accordance with their values and goals in the context of science is referred to as critical science agency. The central thrust in this framework lies in students gaining deep knowledge of science content, process and skills, and then using this knowledge to advance their own goals, goals which emerge out of their social and cultural identity. Tying student identity and learning to each other, it offers a handy tool to comprehend students' reasons for attending undergraduate research programs, their assessments of how useful the (chemistry) discipline is to them and the disciplinary practices that contribute to their intellectual, personal and professional gains in an undergraduate research program.

The study reported here was conducted at an undergraduate research exposure camp held as part of the National Initiative on Undergraduate Science (NIUS) in a premier science education research institute in India. The program provides real time research experiences to first year undergraduate students in the disciplines of chemistry, physics, astronomy and biology. Through such programs, NIUS hopes to foster student's interest in pure science careers as against technology and management ones which are preferred by most talented science students in India (NIUS, n.d.).

In this study, we analyzed NIUS chemistry participants' experiences of the research exposure camp, to understand their interactions with programmatic/structural features of the camp, and thereby study how these features of the NIUS chemistry camp create the conditions under which students develop and express their agency, and closely experience the disciplinary connections. The guiding research question for this paper is how can the NIUS participants' descriptions of experiences be parsed in the critical science agency framework?.

1.1. Critical Science Agency

The framework of critical science agency has been developed by Basu, Barton and co-authors in a series of articles (Basu & Barton, 2009a; Basu et al., 2009b). It was first proposed in a qualitative study by Basu et al. (2009b) to understand how students act in purposeful ways in a physics classroom. The authors documented how physics content and process knowledge enabled students to take actions that brought them closer to meeting their career goals. In other words, how students activated and exhibited their critical science agency in physics in a conducive classroom setting.

The framework of critical science agency starts with the assumption that learning and action (agency) are linked to each other, where action reflects the nature and extent of learning and learning in turn is enriched by the actions undertaken. It underscores the interaction between student identity and learning and the mediating but central role that agency plays between the two. When students successfully engage with a science subject, they use its knowledge and skills to take up roles and activities that expand their identity in directions they desire; this is understood as critical science agency. In other words 'critical science agency' is when students rely on subject-matter knowledge to participate in their social worlds purposefully, meaningfully, and/ or bring about change in their lives. It follows then that this critical agency in science spurs individuals to generate newer opportunities, seek solutions to their problems and explore current and future possibilities while cultivating interest at the same time. It empowers students to become resourceful and use the new resources in light of the goals and aspirations they have.

The 'critical' aspect of critical science agency alludes to the fact that agency in science enables students to bring about a change in their lives. It also includes students becoming critics of science in general through critical thinking as well as being self-reflective critics of their own behaviors and beliefs. The significance of this framework lies in the fact that it keeps students' voices, their self-evaluations and understandings about themselves at its analytical center. It allows us to capture how students see the worth and usefulness of the knowledge they are learning, and to what extent they identify with the subject. It allows the researchers to connect students' practices in a subject with their appraisals of usefulness of that knowledge. Thus it underscores the importance of the subject/discipline to allow students to engage in action that can bring about positive change in their future careers. It also relates to humanizing disciplinary

goals such that students' identities are very much part of their learning experiences and allows them to develop critical consciousness (Shor & Freire, 1987).

The theoretical framework of critical science agency specifically refers to a student's perception of their ability to change their world through everyday actions in line with his/her broader goals in life. One example in the domain of environmental science was where young students exhibited critical environmental science agency by establishing a commitment to collect high quality data in a community and citizen science project ("Fostering Environmental Science Agency," n.d.). Other examples include, a ninth-grader establishing a connection with classroom physics with her career aspiration (of becoming a lawyer) (Basu et al., 2009b), and another set of students who made a choice to avail support for gay and queer youth in the school and embarked on their goal of becoming a graduate eventually (Blackburn, 2004).

2. RESEARCH CONTEXT

2.1. The Setting-NIUS Student Selection Process

The NIUS program was designed as a science talent nurture program for science and engineering undergraduate students in India. The program offers selective students with research opportunities in the subjects of Biology, Chemistry, Physics and Astronomy hoping that the students would experience excitement and challenge while engaging in scientific research, thus encouraging them to undertake research based careers later. The program runs independently for each of the above discipline every year and does not overlap in terms of time. Since the study was conducted in NIUS chemistry, more details for NIUS Chemistry camp are shared.

The selection process for the NIUS Chemistry program has multiple stages. In the first stage, interested and academically well-performing students are selected through a screening process primarily based on prior academic grades and statement of purpose. Typically around 50 students are selected from all across the country and are invited to participate in Enrichment cum Exposure Camp of two weeks. The camp includes lectures on theoretical topics, problem solving sessions, long laboratory exercises, and student seminars. Towards the end, about 30 students are selected on the basis of their performance in the different activities during the camp. These students are then assigned research projects in the area of their interest. The students undergo training and background preparation and then work with their mentors on a proto-research project over two years in summer and winter breaks (2 months in summer and 2-week winter breaks twice). This study was conducted during 2019-20 just before pandemic halted the program for the next three years.

2.2. Nature of Exposure Camp

The sessions in this camp consisted of lectures on core chemistry topics such as thermodynamics, and atomic and molecular structure appropriate for advanced undergraduate students, and interactive sessions on active research areas in chemistry such as drug design and green chemistry. The camp also included workshops on some research and science communication practices including reading scientific articles and writing abstracts.

The afternoons on most days of the camp were reserved for laboratory activities. In the lab task, students were divided into four sections, each section was assigned one problem/exploration in analytical chemistry, organic chemistry, or inorganic chemistry, while the fourth section's problem involved elements of both inorganic and organic chemistry. Each section was further divided into smaller groups of two to three students. The problem solving consisted of thinking carefully about the problem, and formulating a possible route to solving it during the 'pre-lab' session. Students in groups brainstormed about doubts, concerns, and discussed different alternatives that can lead to a solution. Once all the groups had formulated a plan, they presented it to the other groups and the facilitators and received feedback. The facilitators also probed student groups to reflect on what they were doing with the freedom to design and follow their own devised procedures. After discussions, students then moved on to the lab to carry out the experimental procedures devised in the pre- lab sessions.

Each group then began working on its version of the problem solution. The structural features of pre-lab are such that they provide students with a lot of self-exploration and learning opportunities. For instance, in the lab, students come face to face with finer aspects of a physical and/or chemical procedure.

The questions of volume, concentration, time of heating or length of observations invariably surface when students follow their experimental plan which involves conducting chemical reactions. They find themselves making decisions about which chemical to use, what should be its strength, its purity, whether it should be in a solid, solution or gaseous form and so on. They debate and settle concerns such as how long to heat and which solvent to use? Students also learn to handle different kinds of apparatus which they did not have the opportunity to use in their schools and colleges yet. When their experiments did not yield the expected results, they discussed the possible causes and then improvised. In the process they learned advanced laboratory skills and how to solve open ended problems in chemistry labs.

After their labs were over, each group from all the four sections presented what they did and why, what were their results (however imperfect they were), what could have the possible reasons for such results, what did they learn along the way and what could they have done differently.

2.3. Methods

The aim of this paper is to understand how undergraduate students activate and express their critical science agency in the context of a research experience. In order to achieve this aim, we decided to interview students who came to attend the NIUS chemistry camp in the year 2019-20. Since the NIUS camps are organized in four science disciplines-Astronomy, Biology, Chemistry and Physics, the Chemistry camp was chosen by the authors. This is so because both the authors have a background in the physical sciences and one of them (first author) has studied Chemistry till the Masters level. For our study, understanding the nitty-gritties of the subject was essential so that we could engage in meaningful conversations with the students while they are participating in the camp.

As mentioned earlier, first year students pursuing Bachelors' degrees in the natural sciences in colleges, universities and research institutes in the country were eligible to apply for this program. (From 2024 onwards, the eligibility criteria have been changed to include only second year Bachelor's students). The students had either already chosen chemistry as their major or specialization subject or they were studying it as one of the subjects in their Bachelors program. In either case, attending the camp required that students have a strong interest in the subject, and in chemistry research and development.

Among the hundreds of students from all across the country who apply, approximately 55 are chosen for the Exposure cum Enrichment camp (or the research camp). These students are chosen on the basis of their academic performance in class 10th and 12th, their grades in the previous semesters, and the assessments made of them by their two referees. In addition to these public criteria, the NIUS chemistry team mindfully tries to be inclusive and bring in a diverse pool of students to the camp. Since the quality of education varies dramatically with the region and the nature of the institution in India, the chemistry team tries to strike a balance between students who come from elite institutions in urban centers and those who come from smaller state universities in the interior parts of the country. While students from elite research and education institutions have access to human, material, and intellectual resources that meet international standards, those in underfunded colleges and universities do not get enough opportunities to participate in quality learning experiences. Therefore, with these considerations in mind we decided to work with the NIUS chemistry group (of students) which is representative of the country and its diverse higher education landscape. These students had an expressed interest in chemistry, and would have performed well academically too. Because their professors (referees) assessments were also sought, the students were socially recognized as those who might be interested in enhancing their disciplinary learning further. Together with the inclusive practices weaved in the selection of these students, the NIUS chemistry group was the most appropriate choice for our study.

Since our aim was to grasp how students engaged and expressed their agency in chemistry in the camp, we decided that semi-structured interviews would be an appropriate tool. On the first day of the camp, we met with the students in one of the sessions, described our study and sought voluntary participation. While initially only 17 students expressed their keenness to participate in our study but finally more students joined later and we did a total of 19 interviews. The participation in the interviews was completely voluntary therefore. We present an analysis of data from all the 19 interviews.

We designed an interview protocol that contained open-ended questions. These questions were designed to investigate aspects of the students' engagement with the subject of chemistry and with the research camp. The interview tool explored why they applied to and attended the camp, and what was their relationship with the subject of chemistry. Furthermore, what were the activities they participated in during the camp, what did they enjoy (or not), what were the things that they learnt, what were the challenges,

what are their future goals and aspirations, and so on. Our intimate knowledge of the process of the camp (one of the authors was a part of the NIUS Physics and chemistry camps previously), helped us in designing questions around the most salient structural features of the camp with which students interact often for the first time, and which could influence their overall experience of the camp and of the discipline of chemistry.

The interviews were mostly conversational with no strict question order; whatever the student felt comfortable talking about was probed deeper. Since we aimed to capture their life-worlds in relation to the subject and their decision to come to the camp, the interviews took a form of deep and heart-felt conversations where students could express their aspirations and their fears too. Some interviews therefore lasted up to two hours and all were almost an hour long. Because participating in the camp was an exhilarating experience for them, the interview was also an occasion for them to process the multitudes of experiences they were having and to reflect on them. The students seem to genuinely enjoy the conversations and we are duly grateful to them for their time and inputs.

The interviews were conducted in the evening during the five-day long camp. The interviews were done towards the end of the camp so that the students had experienced almost all the activities and were in a position to look ahead and beyond the camp too.

Students were given information about data confidentiality and anonymity, and an informed consent was received from each of them. The interviews were not shared with anybody, and they had no bearing on their evaluation and selection prospects for the longer research project in the NIUS

The interviews were audio recorded and transcribed. We followed both the deductive and the inductive method of coding the interview data (Bingham 2023; Miles & Huberman, 1994). As the aim of the study was to understand how students, with their own values and identities, interact with the features of the camp, in the initial rounds, we coded the data for markers of students' engagement with chemistry, and components of their chemistry/science identity (performance, competence, and recognition). After this round, we read the data again to find out those features of the research exposure camp that were salient to them. Both the authors did both rounds of coding. Through mutual discussions and discussion with an independent researcher in the field who also understands the NIUS program closely, the three categories of students' expression of agency in chemistry were clearly articulated. These three categories (agency before, during, and beyond the camp) illustrate the ways in which students' participation in the NIUS camp both supports and is a product of their critical science agency.

2.4. Analysis

In this section we discuss three salient ways in which students exhibited critical science agency, which indeed became a frame for data analysis and discussions.

While we were initially interested in how the structural/programmatic features of the NIUS chemistry camp create the conditions under which students develop and express their agency, a prominent pattern in students' narratives was that applying/ coming to the camp also was a part of the development and expression of their agency. Students indicated that impressions about past NIUS camps have reached them via other disciplinary networks, and for many students, their application to the camp was a deliberate strategic move. Hence, the first part of our analysis elaborates on the multiple ways in which their decisions and subsequent actions of applying to and attending the camp were instances of their critical science agency.

The second part deals with how students could exhibit agency in the context of different discipline specific activities in which they participated during the camp. Such instances provide evidence for how they activated and increased their critical science agency in this particular setting. In the third section, we present some glimpses of how the experiences of students at the camp provided resources for them to undertake agentic action after the camp. In other words, how their agency at the camp was generative of future possible actions and helped foster their science identity.

3. RESULTS

3.1. Agency while Entering the Camp

The students' decision to apply to the NIUS chemistry camp was a deliberate action taken in accordance with their personal, familial and social goals. The students were highly self-aware; they were aware of how they have changed and stayed the same over the years with respect to their likes and dislikes

for different subjects. The awareness of their current dispositions coupled with concerns about their future prospects influenced their decision to apply for and attend the camp. Each of them was well informed of the value of the camp and they could fashion its significance in alignment with their own goals.

A sizable majority of the students liked one or more science subjects (alongside chemistry) when they applied to the camp. For some, chemistry was not even their most favorite subject. We first discuss the case of students in those undergraduate programs in India wherein in their first year they are not required to declare their majors. Fresh out of school where they have studied Chemistry alongside Physics, Mathematics, Biology, English, and other languages and social sciences, they exhibit a fondness for multiple subjects. They are also aware of the fact that in the next one-two years they will have to make a decision about which subject they will major in. Embedded in this reality, students see the NIUS chemistry camp as the opportunity where they are able to "explore" their interests in the subject.

One of the interview participants, Rishi, talks about using the NIUS camp as the platform that would help him to choose the specific sub-discipline for a future career path.

> *"Of course I'm interested in chemistry. I wanted to explore my interests and which area of chemistry I'm interested in....yeah.. this camp will help me basically in finding out what I want to do and whether chemistry is something I really want to pursue my career (sic)."*

NIUS Chemistry exposure camp is a potential site where students can encounter what advanced knowledge in the discipline looks like and where they also get to partake in some of the knowledge making disciplinary practices albeit in a condensed form. They believe this experience will help them answer questions such as how much do they like chemistry and if it is suitable for their career needs, are they really cut-out for this subject and its demands, how will studying chemistry help them get jobs and so on.

Smart planning towards achieving hhis goals is witnessed in Tanmay's narrative when he decided to attend the NIUS Chemistry camp after having attended NIUS Biology camp previously.

> *"I'd also been a part of NIUS biology program which just happened in October. It was very good...and also since I was initially interested in biochemistry, so I thought biology and chemistry will be a good thing for me, so that is why I thought I'd come for chemistry also….. I just came here to learn some laboratory techniques as far as chemistry was concerned and also to see like when I go ahead further, how much different options I can explore... that was my main purpose for applying chemistry (sic)."*

The other significant group was of students already pursuing Bachelors or integrated Bachelor's-Master's degrees in chemistry. They posited the NIUS camp as a remarkable opportunity to learn advanced laboratory skills and new knowledge in the subject and hence strengthen their bond with it. They see the exposure camp and a future NIUS project as an 'award' or 'token' that will help them get into PhD programs of their choice in the future or help them improve their performance in their current academic programs. While they are moving towards constructing an identity of a chemistry expert, the camp serves as a launch pad into a future of their liking.

Sahil attended the first semester in a foreign university on a scholarship but due to uncertainty related to continuation of his scholarship he had to return to India and enroll in an undergraduate college and start afresh. He is actively seeking research opportunities to build his CV because he wants to ensure that he gets into a master's program of his choice at a foreign university with a scholarship. He expresses simply and powerfully how and why he channelized his energies into coming to the camp.

> *"I don't want to get out after 3 years with just a BSc.…[I thought] why not make something of these 3 years, why not do something extra!.... In my college the amount of research that goes on is not much. ..this [NIUS] was something at least for the next two years I will be involved, I will train myself, will have a bit of experience, so I won't have to run around begging people to take me into their research group...Let's stay back, let's do*

> *this research thing, make my profile so strong that when I apply for masters then that scholarship thing will not be a problem.*

Imad's goal was to beat the competition in his cohort. Before coming to the camp he had studied physics in his college and would go on to study chemistry in the following semester.

> *"I wanted to do something during the winter vacation instead of studying at home, so (wanted to) come here. ....in the first semester only physics is there, chemistry comes in the second semester. So I wanted something of a kickstart for the next semester...Here I'll be introduced to chemistry concepts much earlier than other students so I'll be ahead of all at least in one subject."*

We observed that Sahil, Tanmay, Rishi, and Imad had framed the utility of the camp in accordance with their own aspirations and goals. They actively set their efforts to apply for the camp and generate solutions to the career challenges via their journey to the camp.

Beyond direct connections with disciplinary interests and utilities, the journey of entry to the camp also had some other societal facets. During the interview, we realized that some students talked about seeking approval from their parents to attend the NIUS camp as it was being held in another distant city. The collective nature of Indian society and societal values of involving parents/elders in decisions-making (related to career, travel, moving, companionship etc) is a dominant trend in many Indian families. The situation is a bit more challenging for girl students. We could observe some such influences in students' decision-making about the NIUS camp.

During the interview, a few participants shared stories of 'convincing parents' and 'requesting teachers to write recommendation letters'. They also stressed on the fact about how they on their own initiated some tasks required to participate in the camp successfully. Ashwini shared her experience of how she made sense of her reality, and chose her strategy of convincing parents to agree with her decision to travel to Mumbai to attend the camp.

> *"Generally our problem is kids cannot explain to their parents why they want to do what they want to. Because when for the first time I told my father that I want to go to Mumbai, he was like Ashwini, you have never gone out of Delhi by yourself alone...how will you go to Mumbai alone? Then, when I explained to my father why I want to come here, then he was like okay, now that you have explained [to] me...because generally kids at this age, they wonder why should they have to explain anything to their parents, they should understand it on their own. But yes when you explain, they will definitely understand those things, then it will be a good thing and they will accept your desire too. If they do not accept then according to me you haven't explained to them well why you are trying to go there. Because parents ultimately want the best for you so they will definitely understand. So when I explained to my parents, to my father, my mother why I want to go then instantly they were like yes you can go….."*

Similarly, Imran's words show how he approached his teachers for help immediately after learning about the camp from a peer.

> *"I have a senior from my school...he came for the NIUS physics program… He is like my childhood friend…when I told him that I am joining [his undergraduate institute for Bachelor's degree] and asked what do you say about that [institute and course]. So he said yeah it's good. But there's this program …NIUS chemistry ..we talked [briefly] about it. So I think, on day one...yeah, the day when I joined my institute, our first meeting with all the faculty from the chemistry stream...the first question I asked was how can I apply for the NIUS camp? …. and they were like....okay, we'll get to that later..."*

Like Imran, many participants were informed of the camp by their teachers, seniors and friends who

believed that it would benefit them. These students were recognized by their peers and teachers for their interest in chemistry and they mobilized resources (information, recommendations etc.) which would help answer their questions to advance their careers. The students leveraged their interest in the subject, their short and long term concerns for their future and the information gained from others around them to put into gear a series of events which brought them to the camp thus exhibiting and developing their agency in chemistry.

It is worth emphasizing here that though these tasks and actions may look trivial,, they should not be understood as such. These are deliberate attempts by students towards their careers. Their agency consisted in using their expertise in chemistry and knowledge of the importance of the camp, knowledge of how their parents think, and their social identity to overcome all kinds of obstacles. In the large population of students pursuing undergraduate studies, not every chemistry undergraduate has enquired or applied to the camp, nor all have analyzed what can benefit their career trajectories as can be explicitly seen in the above examples.

3.2. Agency at the Camp

The nature of activities in the camp required students to critically think about the problems with their disciplinary knowledge. In their pre-lab sessions, participants decided on a plan of action to tackle the problem; working in groups they discussed what prior concepts and theories were relevant and devised a stepwise scheme for solving the problem.

When asked to elaborate on their camp experiences, participants kept comparing the way they did labs in their schools/colleges versus here. Based on their articulation, in the former, the lab practicals were protocol based. They were mostly given a problem for which they had to follow a pre-designed procedure to get the results which were known too. There were no options to tinker with the procedure, no options for deviating from the course. In contrast, at the camp, participants had to collectively brainstorm on the problem to understand it and decide how to proceed. No strict, codified procedure was presented to them. The camp facilitators explained the problem and facilitated students to direct their attention to known, observed, and estimated/calculated entities of the problem. Participants were encouraged to chart their way to the problem solution as against being prescribed a path that led to the one and only solution. Manasi explains the difference between her pre-lab experience here and her college lab practical explicitly.

> *"Learning chemistry in the way we did it in school was a way lot different than the type of experience I had in this [camp]....the way we looked at the errors at our lab experiments at school was- emm, if we had any errors, then teachers would say "forget about the error and start again" to get the exact set of results that they want. Here, we don't assume our results. We analyze our errors and results to know exactly why this thing has happened. ...definitely they [camp facilitators] also would like to know that as we like to think why did that happen exactly..."*

In another instance, Sonal explained why she enjoyed the problem her group was trying to solve.

> *"For the first day when facilitator was introducing the problems, I secretly was hoping that our group gets indigo dye problem, I felt that others like titration were simple, but when the other day I was talking to by roommate and she explained that it is much complex then simple titration, I was still hoping to get indigo dye problem, it was thrilling as we were just given some waste water and told a little about what to do with it, we had to find out everything on our own, we figured out that we needed to analyze waste water by determining its pH, and thus know about how indigo dye reacted with fibers and waste water was generated, we had some help but the building blocks were certainly laid by us, it was a new project and turned out to be good problem.*

This change in the nature of investigation and unique problems equipped participants with cognitive and affective tools to excel in chemistry. Participants learnt not to run away from errors but investigate

them as a way of learning. When trying to explain the possible reasons for errors, one is forced to review the design, calculation, and experimental decisions again. Problem solving in this way allowed students to exercise their agency in finding solutions and implementing them and learning from their mistakes.

Students not only thoroughly enjoyed the challenging and stimulating approach to problem solving, they felt confident in and closer to the discipline of chemistry. It is evident that they felt compelled to convey their error analysis to the camp facilitators (an action that their college teacher had discouraged). Thus, the structure of pre-lab made students feel responsible for the task at hand and propelled them to take further action to not just solve the given lab problem but even go beyond it to enhance their disciplinary practice related to research data in general. Similarly, Sonal's excitement suggests that the problem provided many discussion and exploration opportunities than what they had come across previously and made the problem a field for exhibiting her newly evolving disciplinary skills.

Working in groups, participants were encouraged to do some background research, bounce ideas off each other, find a tentative solution, implement it, get some results, and if they were not satisfactory, go back, find another solution, discuss and repeat the cycle again. At every stage, facilitators would ask them questions to understand how the students were reasoning, what their rationales were for taking a particular step and how it fit with the larger problem solution. Questions by their own peers and teachers compelled them to examine their own thinking and reasoning processes until they arrived at a solution. Raj explains,

> *"The main thing was that we were self-dependent...we had to see why this is happening and so on...they made us think like why do you think these observations are coming and not the other, why do you think this pH?, yesterday only we had such a long discussion [in group] that we slept at 5 AM…"*

This process of working in the lab activated their own agency in handling the subject knowledge, the experimental procedures, and materials--skills and competencies which were mostly dormant in chemistry labs in their schools/colleges. Raj in his example pointed out that the niche of their group's problem was to analyze the pH of waste water, but core to it was what does that value of pH reveal about the nature of waste-water, and thereby the nature of dye, and the coloring process with the indigo dye. These inquiries led to some extended and fruitful discussions during the camp.

The feedback on their actions/discussions fueled them to learn more and hence do more. In this process, participants learnt to take responsibility for their learning and its application. At the same time students improved on more pragmatic aspects of managing time and resources.

> *"Here we had to do everything on our own. So, learnt how to handle things myself, learnt time management myself like how to finish this experiment in this time. So it made me more self-responsible, more responsible for my actions.."*

After a few setbacks in the lab when it came to not managing time effectively and lagging behind in their schedule, students of their own accord refined their ways of managing limited laboratory time. Isha shares one such story.

> *"After we messed up on the first day, from next day we started planning our activities [with my lab partner]….you do this, I'll do this..we started dividing the time when taking observations and doing other things in the lab."*

During the camp, participants would spend time beyond their lab hours to discuss their lab problems and results too. They would look up resources on the internet, seek help from other students, divide tasks and thus keep moving ahead. The students were also critical and reflective of their own performances and were improving each day. Namrata added,

> *"We used to sit outside the hostel area and discuss our lab work, search the internet…someone in our group had already done complexometric titrations, so he also helped...we could reach the conclusions by ongoing discussions."*

Finally, juxtaposing excerpts from Mohan and Nitin who were partners in the lab group illustrates another instance of students developing agency in chemistry.

> *Mohan: "Just for the first time we have been exposed to such a situation, I mean, we were given a problem to solve it in a span of 5 days approximately. It was a mind boggling problem obviously. We had to work in the group. What Nitin (the partner) and I did was that..I proposed two ideas, he proposed two ideas, we discussed upon them just as we were discussing, I mean there was a group discussion! We shoot questions upon each other"*

> *Nitin: With the problem each of us would say what comes to mind directly without going too much deeper into it. Preliminary ideas would come out about what to do about this and…perhaps some of them will be reverted...then we go deeper into what would have caused this .. .and mostly... we reach consensus."*

As can be seen, both Mohan and Nitin embarked on a group discussion to share their ideas about navigating towards problem solution first, and for choosing how to proceed, and strategized a consensus establishment in the group. Both enjoyed the novel way of addressing a problem for a considerable length of time and attention, and enjoyed the freedom provided during problem exploration, yet equally sensing the responsibility to make significant effort to convince the entire group about their approach.

Similar to Mohan-Nitin and other members, presented with a novel problem and a different context, participants in the camp improvised and formed their own routines to discuss and solve them in their groups and their lab partners. They exercised their agency in finding their own ways of working in the group, managing time, questioning each other, defending their answers and solving problems together.

3.3. Agency beyond the Camp

In this section, we would like to discuss some glimpses of how the experiences of students at the camp provided resources for them to undertake agentic action after the camp. Participants regarded what they learnt during the camp with significance and used that knowledge to advance their educational and career interests further. Their experiences at the camp were generative of future possible actions in the discipline of chemistry.

In the camp, some participants mentioned that they learnt of research opportunities they could explore once the camp was over, some others described some topics in chemistry discussed during the lectures which they decided to pursue in their undergraduate courses and learn more about. The camp experiences and learnings provided them with additional avenues where they could exercise and build their agency in chemistry. The camp enhanced the agency of students by exposing them to content and process knowledge in chemistry which opened up alternative pathways for them to consider.

Camp participants generally recognized that there was a lot they did not know, that they had to learn much more before they could become scientists. The NIUS camp attracts students from different kinds of institutions located in different parts of the country. While some students come from under-resourced undergraduate colleges located in interior regions, some from elite research-intensive universities and institutions also attend the camp. A number of students embrace this diversity, they described the camp as "mini-India" owing to the diversity of students who participated in it.

Their interactions with each other in the lecture halls, laboratories and cafeteria among others enabled them to gauge their present level of learning and how much more they can learn by themselves and from each other. Most of these students had done well academically in their respective schools. School

performance was one of the criteria on the basis of which selection for the camp was made. Having done well and gathered praise for their performance till now, when they came in contact with others who too had done well, these students were filled with a desire to expand their knowledge even further. A number of them were positively amazed at each other's learnings and showed enthusiasm to use these learning experiences to improve their own work.

Ashwini, who was working on a research project at her undergraduate college, was preparing a manuscript on it. She had written an abstract for that paper under the guidance of her college professor. But after attending the session on abstract writing at the camp, she decided to take charge and revise it.

> *"When we were writing abstract for our review article on anti- cancer agents, I did abstract writing for that paper 10 times. And each time my sir found different mistakes. So I refined myself a bit from that experience. And when I came here and discussion on abstract writing happened and students expressed their different points...till then my views of abstract writing were my own, from my sir, but here I got to learn the ideas of forty-two other students ...even when I go back to my college and continue my paper I think I will make a lot of modifications to what I have already written because I learnt so much after coming here on how to write a research paper."*

Isha had not studied quantum chemistry in her school or in the first semester of her undergraduate program. After attending a lecture on the topic in the camp, she was mesmerized by it and decided to study it more deeply once the camp was over.

> *"I loved this camp..I had to work a lot, I had to think a lot, I learnt to work in groups..since school I have been working alone... I think I have improved a lot...and then my passion for learning chemistry also increased...like one of the lectures was on quantum chemistry and we hadn't studied it yet but now I feel I must study, my passion for it has increased. "*

Like Isha, other students argued that topics like statistical mechanics, quantum chemistry are introduced much later in their undergraduate years and its introduction in the exposure camp has made them excited about these academic courses now itself.

We witnessed many such accounts where students expressed their desire to apply their learnings to other chemistry related things in their lives after the camp, may it be learning a specific academic topic, or revisiting some research work they have been involved in, or even in exploring if next the phase of NIUS can provide them with such opportunities. In the process, they develop a sense of autonomy; they are ready to take actions and accomplish things without any prompts from others.

4. DISCUSSION

While the focus of the study was to understand the emergence, development and expression of students' critical science agency in the NIUS camp, and thereby also to shed light on how the structural/programmatic features of the camp create the conditions under which students exhibit markers of critical science agency. An almost invariable feature of student's narratives was how their decision to apply for the camp was an expression of their agency, a deliberate action taken in accordance with their personal, familial and social goals. So, though we began our study to understand how students' critical science agency emerges during the camp, student narratives were replete with stories of how other sites and experiences in their educational trajectories may too have contributed in fostering science agency at times.

As Basu and Barton claim, an expression of science agency is when students see science as a context for change such that it allows them to evolve their scientific identities (Basu & Barton, 2009a). In examining Sahil's entry level experiences to the NIUS camp, it was clear that Sahil wanted to stand out as an extraordinary undergraduate student. The emotion was stronger due to the added circumstances in which he had to start afresh in his bachelor's degree in chemistry in the country. He banked on the idea that NIUS

camp is an avenue that could provide him with a substantial research ground in chemistry and also serve as a gateway for applying to a good master's program.

In other cases, like Rishi and Tanmay, they were thinking of NIUS camp as a platform to sense how the chemistry research domain is and thereby decide if they would like to advance in it or make an area-switch. In the case of Imad, he was seeing that early exposure to subjects through NIUS increases his chance of performing better than his academic peers back in college. More narrowly, in all these cases, participants felt that their identity as an NIUS camp attendee would give them a head start in their personalized goals. The criticality lies in taking a stand that the NIUS camp will clarify their future expectations from the chemistry discipline in their own career trajectories, and therefore help them decide if they want to apply for higher education in chemistry in the first place.

In dealing with application decisions related to the camp, students drew resources from their schools and peer networks. Underscoring the agency of students while entering the camp helped us to capture the good practices in which institutions outside of NIUS camp are engaging the students. The participants talked about teachers' support in informing about the program when requested on the first day of undergraduate studies. The participants also leveraged resources from their social, cultural context as well. The information about NIUS camp was percolated to potential applicants through their senior peers.

From Ashwini's story, it was evident that Ashwini is representing many Indian women-students whose gender identity in a setting of strong family values demands developing a skill of 'convincing parents'. While Ashwini makes use of the knowledge of family settings and the value-system in which her family believes to convince her parents, her convincing is centered on traveling and is not necessarily about conveying the importance of the NIUS camp. Acknowledging the societal circumstances, Ashwini's act of convincing her parents about a travel to another city is genuinely to enhance her chances of going to the camp. A limited view of science agency may restrict us to account for actions related to strictly science-related enactments alone, but the criticality also lies in honoring the participants' subjectivities and how they in turn portray their agentic behaviors as a budding member in the communities of practice in the science domain. Ashwini's act of convincing her parents was a deliberate move to express her science agency to her parents, and also sharing it as an important entry level experience with us.

The next part deals with how participants could exhibit and develop agency in the context of different activities in the camp. They could channel chemistry knowledge as well as other resources in a way to bring about meaningful differences to their lives in a way that expanded their participatory identity as a team-player, as a collaborative decision maker, and the one with some advanced experience in chemistry research. Many narratives indicated participants' likings about group norms like providing equal opportunities to propose problem solutions, warranted discussions about potential solutions based on disciplinary knowledge base and lab skills, and need to build a consensus to move forward. In some ways, the exposure camps were enhancing their science of science research as a collaborative endeavor.

Sonal's narrative suggested her satisfaction about taking a relatively new (indigo dye) project to the point where she felt victory of achieving a goal. Her keenness about contributing to a newer project by making appropriate experimental efforts was for getting disciplinary recognition in terms of the subject knowledge as well as being a good team member. Thus, participation in the indigo project allowed Sonal to see herself as a successful and powerful learner of chemistry, a strong marker of critical science agency.

Similarly, Manasi's brief about learning from errors shows her criticality to get real and authentic data, another example of expression of science agency. Both of them have been associated with chemistry discipline in school and college, but the NIUS camp provided them a chance to experience expert-like thinking via unique problems. Moreover, Raj, Isha and Namrata discussed how their extended discussions with their group members provided support at crucial junctures of experiments. The distribution of work-responsibilities was a careful and well thought out move by the group to speed up and include diverse perspectives and refine their participatory identities.

In science agency literature, apprentice-style undergraduate research has been reported to provide students a sense of self-authorship (Magolda, 1999). The research problems allowed the participants to closely work with fellow group mates, closely follow facilitator's feedback, shadow group members and facilitators at times, yet take responsibilities of their group project. Like Sonal and Manasi, other participants

also had moments when they experienced the sense of responsibility about their own data, proposed research design, and influenced the overall success of their problem solution.

Mohan and Nitin's stories further indicate how collaborative-decision making was an unsaid norm of the group, and that each contributed in it faithfully with a common goal to navigate through the problem solution successfully. The challenges were also tackled via discussions. In identity literature, similar work setting like research laboratories and fieldwork settings acknowledge the importance of group-work in identity formation (Valutis et al., 2012).

We also see how their experiences in the camp nurtured their agency in chemistry--both for the proximal context of the camp and the distal one beyond it. Participants were thinking deeply about how they will utilize their learning in the camp for what they will do in future. And, in this goal- oriented planning based on learnings and experiences in the camp, we see students bringing autonomy to their actions, wanting to take control of situations, and hence exhibiting agency. In Ashwini's example of abstract writing, we see her changed mindset after the NIUS camp experience, particularly after witnessing the abstract writing activity. She expressed her evolved understanding about the feedback process and how multiple perspectives could add value to a written artifact, and in general to the science enterprise itself.

In the case of Isha and a few others, their excitement of exposure to topics like quantum chemistry, statistical mechanics in the camp allowed them to streamline their future efforts to strengthen their disciplinary ties with chemistry.

5. CONCLUSION AND FURTHER IMPLICATIONS

Based on the participants' experiences, we conclude that participants express science agency at all the three stages, at the entry to the camp, during the camp, and beyond the camp. At the entry level, participants attach significance to the camp in light of their own values, goals and aspirations, and thus decide to apply for or finally attend the camp.

On a broader spectrum of takeaways of the research, having knowledge of such pre-camp experiences of participants is useful for mentors at the camp so that they can have more focused talks about participants' unique interests and aspirations and can provide exclusive mentoring to participants on their questions. It is timely important as such talks can support participants' decision-making for future career goals. The undergraduate research exposure programs thus should create some space as a routine programmatic feature where participants get to spend some time with their camp mentors to explicitly interact on their pre-camp experiences, goals and aspirations.

While this interpretation is from students" entry level experiences at the NIUS camp in India, globally, undergraduate mentors can consider incorporating these interactional spaces as a regular programmatic feature for similar undergraduate research programs, particularly when students are interacting with mentors and other group members from diverse backgrounds.

The participants valued the NIUS camp experiences particularly due to the nuanced nature of problem-solving in which they had to engage; an extended lab activity of nearly a week, which mandated participants to work in groups. Both the structural features provided participants with an opportunity where they could sense themselves as a powerful and successful learner of chemistry and a contributory group member while participating in niche disciplinary problems. As mentioned by Linn et al (Linn et al 2015) such experiences are perhaps bringing NIUS camp participants closer to the genuine research endeavors where participants get to do more beyond just replicating a set lab experimentation. Therefore, such programmatic features are worth incorporating in other similar undergraduate research programs globally rather than rushing to accomplish multiple lab rotations schedules.

Also, working in groups brings the participants closer to the idea of how science is and should be viewed as a collaborative endeavor rather than solitary contributions. With national education policies worldwide supportive of cooperative learning methods, the undergraduate research experience camps can also align their efforts to nurture these co-working skills in students.

It is important to note that the critical science agency framework has not been explored much in the context of undergraduate research experiences. Our work with NIUS camp students shows students

engagement with research experiences not only enhances their science identities understood in the traditional sense but also engages and develops their critical science agency with which they are set to make their lives better by their learning and contributions in chemistry.

Moreover, we interpreted that NIUS participants were processing the significance of the camp or attaching meaning to its different experiences in alignment with their own aims -both short and long-term objectives. Finally, participants also enjoyed the humanizing experiences of chemistry where their group together was involved and responsible for a meaningful sensemaking of chemistry problems, and felt the tensions, stumbled at roadblocks, and celebrated victories.

The NIUS camp students' experiences validated that these students expressed science agency at all the three stages, at the entry to the camp, during the camp, and beyond the camp. Perhaps, the opportunities at the camp and interviews allowed them to reflect on their past study/research experiences, and similarly share their plan for future endavours, and importantly putting their current experiences in a perspective. What this offered in terms of research? We believe that our study shows that the gains in students' science identity and agency in the context of the research exposure is intimately linked to their agency before they have the exposure and goes beyond the exposure.

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